LOGIC

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BOOK III.

INDUCTION.

CHAPTER I.

MEANING AND SCOPE OF INDUCTION.

1. Induction is the arriving at General Propositions, by means of Observation or Fact.

In an Induction, there are three essentials:—(1) the result must be a *proposition*—an affirmation of concurrence or non-concurrence—as opposed to a Notion: (2) the Proposition must be *general*, or applicable to all cases of a given kind: (3) the method must be an appeal to *observation* or Fact.

(1) By Induction, we arrive at *Propositions*,—Affirmations of coincidence or non-coincidence of distinct properties; we have to do, not with verbal, but with Real Predication. That 'The boiling temperature destroys animal life,' is an induction so far as being a proposition, affirmation, or real predication; there are two distinct facts—boiling heat, and destruction of animal life—and these two facts are coupled in an affirmation of coincidence.

To this essential of Induction, are opposed the cases where what we arrive at is a Notion or Definition. Sometimes we are liable to confound the two. This happens when we are attending too exclusively to the second characteristic of Induction—generality. In the process of defining, we generalize a number of individuals, so as to obtain and express their point or points of community, which expressed community is a Definition or Notion; as Heat, Knowledge, Justice. If such definitions, or expressed general notions, are absolutely limited to *one* indivisible fact or attribute, they are by that circumstance decisively contrasted with inductions, which always join

at least *two* facts or attributes. Thus, the generalized notions of length, resistance, whiteness, heat, could not be confounded with inductions; there is clearly absent from these the conjoining or coupling of distinct properties. But we have seen many instances where a definition expresses a plurality of attributes concurring in the same subject, as in all the natural kinds—minerals, plants, animals—and in various other things. There is no small delicacy in placing the boundary between those generalities ending in plural notions, or definitions, and proper inductive generalizations. We have to ask whether or not the stress is laid on the circumstance of *conjunction*, whether it is made a question—*are* the properties conjoined or not. In definition, the conjunction is tacitly assumed; in induction, it is laid open to question; it has to be *proved* or *disproved*. (See p. 62).

(2) The Propositions established by Induction are *general*. A single individual concurrence, as 'the wind is shaking the tree,' is in its statement a proposition, but not an induction. On such individual statements, we base inductions, but one is not enough. If the coincidence recurs, we mark the recurrence; we are affected by the shock or flash of identity, a very important step in our knowledge. If, pursuing the suggestion, we remark that as often as the wind is high, the trees are shaken; that the two things have concurred within the whole course of our observation; that the same concurrence has been uniform in the observation of all other persons whose experience we have been informed of,—we are then entitled to take a still wider sweep, and to say, 'every time that a high wind has been observed, a waving of the trees has also been observed.'

Still, with all this multitude and uniformity of observations, there is no proper Induction. What then remains? The answer is, the extension of the concurrence from the observed to the unobserved cases—to the *future* which has not yet come within observation, to the *past* before observation began, to the *remote* where there has been no access to observe. This is the leap, the hazard of Induction, which is necessary to complete the process. Without this leap, our facts are barren; they teach us what has been, after the event; whereas, we want knowledge that shall instruct us before the event, that shall impart what we have no means of observing. A complete induction, then, is a generalization that shall express what is conjoined everywhere, and at all times, superseding for ever the labour of fresh observation.

We thus contrast Induction with that species of 'Inductions improperly so called,' where a general statement merely sums up the observed particulars.

If, after observing that each one of the planets shines by the sun's light, we affirm that 'all the planets shine by the sun's light,' we make a general proposition to appearance, but it falls short of an induction in the full sense of the term. The general statement is merely another way of expressing the particulars; it does not advance beyond them. But without such an advance there is no real inference, no march of information, no addition to our knowledge. Induction is the instrument of multiplying and extending knowledge; it teaches us how, from a few facts observed, to affirm a great many that have not been observed. If, from the observation of the planets now discovered, we make an assertion respecting all that have yet to be discovered, we make the leap implied in real or inductive inference. If the assertion had been made when only six planets were known, actual observation would have been the guarantee for those six, induction for the remaining hundred or upwards.

So the proposition 'all animals have a nervous system' is an induction only when affirmed on the observation of a part of the animal species. If the representatives of every species had been examined before the statement was made, the proposition would be proved by observation, and not by induction; the generality would be merely a literal repetition or summary of the particulars.

This kind of improper induction is assumed in the attempt, made first by Aristotle and repeated by others, to bring Induction under the syllogism. Induction 'is defined by Aristotle, "proving the major term of the middle by means of the minor;" in which definition, the expressions *major*, *middle*, and *minor*, are used relatively to their *extension*, to designate respectively the attribute proved, the constituted species of which it is proved, and the aggregate of individuals by which the species is constituted.' (Mansel's Aldrich, Note G.). Thus—

X, Y, Z, (*minor*) are B (*major*),
X, Y, Z, are all A (*middle*),
All A is B.

This has the appearance, but only the appearance of a syllogism in the Third Figure. It is liable to the criticism already made upon syllogisms with two singular premises. It is not a syllogism at all, in any correct sense, but a mere process of equivalence. The two premises can be summed in one, by verbal or grammatical condensation; and when that has been done, the conclusion is a mere repetition of part of the meaning of the combined statement.

A more ambitious form of the Inductive Syllogism is given by Aldrich and Whately, which trenches on Induction proper.

The magnets that I have observed, *together with those that I have not observed*, attract iron.
These magnets are all magnets.
All magnets attract iron.

The major here obviously assumes the very point to be established, and makes the inductive leap. No formal logician is entitled to lay down a premise of this nature. The process altogether transcends syllogism or formal logic.

In no sense is the Inductive Syllogism an admissible logical form.

A truly inductive Proposition may be but a narrow generality. That 'the breeze always spreads the royal flag hoisted at Windsor Castle' is a proper induction; it covers the unseen and the future as well as the seen. The still wider induction, 'the breeze spreads all the flags of all nations,' is not more essentially inductive, although of more value as knowledge.

(3) An Inductive Proposition is based on the *observation* of facts. Many true propositions, instead of being based on a direct appeal to observation, are derived from other propositions; such are, with a few exceptions, the propositions of Mathematics, and many truths in all the other sciences. In this view, Induction is contrasted with Deduction. Induction is necessarily the prior source of truths; the Deductive propositions are obtained from Inductions. We must commence with observation of fact, and thence rise to Inductive generalities, before we can proceed downwards in the way of deduction.

By the use of our observing faculties for the object world, and of self-consciousness for the mind, we not merely obtain our notions of things—stars, mountains, trees, men, pleasures—but also discern the conjunctions or connexions of things. A single conjunction excites little notice, but an iterated conjunction awakens our feeling of identity; we attend to the circumstance, and watch for the recurrence. If, in the midst of fluctuation, some one couple of things is found always associated, we state the fact to ourselves as a natural conjunction, a law of nature; and the statement is an inductive proposition. A meteor flashing along the sky is an isolated circumstance; we term it casual or accidental. The recurrence of a stream of meteors year after year, in the same month, is a coincidence, which we elevate into an induction, affirming it for the future as well as for the past.

The semblance of Induction is put on by certain operations

purely *Deductive*. Of these Inductions improperly so called, two forms may be mentioned.

First. There is a certain likeness to Induction in the demonstrations of Euclid; which are each made upon an exemplary diagram, and thence extended to all similar instances, by what is termed *parity of reasoning*.

When Euclid proves that the angles at the base of an isosceles triangle are equal, he proves it upon a single diagram, and rests the general proposition upon the circumstance that the same result would be arrived at in every other case of the same sort. The resemblance to Induction lies in extending what is found in one instance to all other instances. Yet the resemblance fails on vital points.

In reality, such truths are not established by measuring the particular diagram, and recording that measure as an observed fact, to be taken with other facts similarly observed, in making up a general rule; as if we were, by means of an induction from the pyramids, to lay down a general law of pyramidical structure. The only use made of the figure is to provide a concrete reference in applying the *general* language of the demonstration. One triangle is as good as another for the purpose. We expressly omit from the reasoning all reference to the size of the triangle, to its material, to the size of the angle included by the two equal sides; consequently, our proof is independent of any one of these elements, and holds under all variations of each. The demonstration is to the effect that, *quoad* isosceles triangle, the affirmation is true; it is a perfectly general truth. The expression, 'the same *might be* proved of any other isosceles triangle,' would be idle and superfluous; the fact is already proved of every such triangle.

Secondly. The term Induction has been improperly applied to discoveries of *identification to establish a minor*—a purely deductive operation.

When Kepler, after comparing a great many positions of Mars, came to the conclusion that all these places lay in an ellipse of certain dimensions, he made an advance from the known to the unknown, which is one criterion of induction. Without any farther observations, it was possible to assign the place of the planet at any moment of time throughout the entire circuit. Yet, notwithstanding this remarkable peculiarity, the case is not an induction. It is, in fact, a *deduction*. We might term it a discovery of identification to establish a minor.

Supposing that, in the time of Kepler, the geometrical pro-

positions of the ellipse had been still undiscovered, he could not have established his law, nor applied it to fill in the intermediate places of the planet. What he really discovered was an *identity* between the series of observed positions of Mars and the path of an ellipse with the sun in the focus. It was by the help of the known properties of the ellipse that he made this identity. The identity once established, any or all of the propositions of the ellipse could be applied to the orbit of Mars, and by these the orbit could be as it were drawn, so as to show the successive positions of Mars as he described his circuit. There could have been no inference from places observed, to places unobserved, except through the application of those laws respecting the ellipse, which had been discovered by the Greek geometers. The propositions of the ellipse supplied the major premise of the reasoning. Kepler's observations supplied the minor premise; they showed that the places of Mars coincided with the places in an ellipse; whereupon whatever was true of the ellipse was true of the orbit of Mars.

Similar instances of discoveries of Deduction could be cited. When after the inductive establishment of the laws of magnetism upon Iron, other substances were discovered to be magnetic as Nickel, Cobalt, Manganese, Chromium, &c., the magnetic laws were forthwith transferred deductively to these bodies. Franklin's great discovery of the identity of lightning and electricity, enabled all the previously ascertained facts regarding electricity to be applied to the atmospheric charge.

In contrast to the law of the elliptic orbits, we may quote Kepler's third law—the relation of the periodic times to the mean distances, an induction in the proper sense of the word. There is still a mathematical element present, but that element is not the major proposition, to which Kepler supplied a minor. The numerical ratio merely expresses the point of concurrence of the particulars observed, it being the nature of that concurrence to be numerical. The basis of the induction was the agreement of the six planets in the numerical ratio; and the induction was brought out in its real character when new planets were discovered and the law applied to them at once, and before there was time to observe the fact in each individual case.

Of a similar nature to Kepler's third law is the law of the refraction of light, a proper induction set in mathematical language. From a number of positions of the incident and re-

CHAPTER III.

INDUCTION OF CO-EXISTENCE.

1. Of Uniformities of Co-existence, a very large number may be traced to Causation. It remains to be seen whether there be any not so traceable.

The numerous Co-existences of Order in Place, or the distribution and arrangements of material objects throughout the Universe, are all the results of causation, starting from some prior arrangements. The distribution of sea and land, the stratification of the earth's crust, the existence of an atmosphere, the distribution of the materials of the globe generally, —are the result of natural agencies or forces, operating upon prior arrangements. Salt is found in the ocean, because the water has dissolved all accessible portions of it. The heavy metals are found in deep rocks in consequence of their weight; the corrosible and combining metals occur in combination; and those that are reluctant to combine, occur nearly pure, as Platinum and Gold.

There are thus no independent laws of co-existence to be found among uniformities of Order in Place. We must seek for them, if there be any such, among CO-INHERING ATTRIBUTES. It is possible that attributes or properties not connected as cause and effect, may yet be conjoined uniformly through all nature. If so, they are likely to be found among the natural kinds— Minerals, Plants, Animals. The conjunction of body and mind in man, and in the animals, is to all appearance such a case as we are in quest of.

2. It is the special peculiarity of the Natural Kinds to combine many attributes in unity of subject. In them we have the chief exemplification of co-inhering attributes; and they seem to furnish uniformities of co-existence.

Thus Gold unites a certain specific gravity (19.3), crystallization (cubical), tenacity, fusibility (melting point, 1200° C), colour and lustre (yellow), electrical conduction, atomic weight (196), combining properties (acted on by *aqua regia*). These are eight leading attributes that concur in every piece of gold;

and unless we see our way to deriving some of them from others, we must pronounce them *essentiæ*, essential or defining attributes of gold. There is a co-existence, or co-inherence of these eight facts, with others, in the object named gold.

To appearance there is here a uniformity of co-existence. No specimen of gold is devoid of any one of the eight properties. Properly speaking, however, this is merely affirming an identical proposition. Should there occur a specimen wanting in one, two, or three of the eight, we should say not that a law of co-existence was infringed, but that a different substance was produced. If these be the essential attributes of gold—the meaning or connotation of the name, then, on the failure of any one or more, the name would cease to be applied, the substance would not be ranked as gold, it would be classed as a new and distinct substance. Gold with the specific gravity of 9, or with a silvery colour, or with a liability to corrode, would not be gold, it would be treated as a different material, a distinct grouping or aggregate of powers and properties. If there be any one of the now enumerated properties of gold that we could see changed and yet keep up the designation gold, that property is declared not to be the essence, but a *concomitant* of gold. A proper inductive enquiry would hold in such a case.

3. For a Law or Uniformity of Co-existence, properly so called, we must refer to examples, if such there be, where two or more independent properties are conjoined through all nature, or in all substances where one of them occurs.

We must search among the properties of kinds—mineral, vegetable, and animal, for some that are coupled throughout every species, and under every variety of aggregation. For example, could we find a certain crystalline form regularly conjoined with certain chemical characters, not in one substance only, but in *all substances* possessing that crystallization,—this would be a proper law or uniformity of co-existence. There would still remain a question, often difficult to settle—whether, on the one hand, the two are mutually implicated properties, or, on the other hand, whether they are connected by cause and effect.

To detect such uniformities of general co-existence, among the essential properties of mineral bodies, whether simple or compound, is a proper object of scientific enquiry. Nor has it been neglected by physical enquirers. The following are the leading examples obtained up to the present time.

(1) A law has been discovered connecting Atomic Weight and Specific Heat by an inverse proportion. For equal weights of the simple bodies, the atomic weight, multiplied by a number expressing the specific heat, gives a nearly uniform product. Thus, for sulphur, the atomic weight (32), multiplied by the specific heat (0.1776), gives 5.68; the atomic weight of platinum (197), multiplied by its specific heat, (0.0324), gives 6.38. The products for all the elements are near the constant number 6.

(2) A law obtains between the Specific Gravity of substances in the *gaseous* state and the Atomic Weights. Thus, the specific gravity of oxygen is 16, its atomic weight 16; hydrogen, specific gravity 1, atomic weight 1; phosphorus, specific gravity 62, atomic weight 31 (the relation here is 2 to 1); steam, specific gravity 9, atomic weight 18 (relation of 1 to 2). The relationship of the two numbers is thus, in some instances, equality; in other instances, the one is a multiple of the other. The law is one of importance in ascertaining atomic weights.

With an exception to be noticed presently, these are perhaps the two most widely-operating laws, as yet discovered, whereby two distinct properties are conjoined throughout substances generally. There are various laws of narrower range, as, for example, Andrews's laws of the heat of combination of the metals.

√4. A peculiar importance belongs to the law of universal co-existence uniting the two properties — Inertia and Gravity. These properties are co-existent through all matter and proportionate in their amount.

Inertia, the defining attribute of matter, means both resistance to movement, and force when moved. It is totally distinct from gravity. A body rolled on a level surface shows its inertia; so also do two weights equipoised, as in the beautiful experiments of Attwood. Now, all inert matter gravitates; and the force of gravitation is proportional to the inertia. Equal weights, (which are the estimate of gravity), are equally resisting to a horizontal impulse (the measure of inertia) or to a vertical impulse in the balanced condition.

It cannot be maintained that these properties are mutually implicated. We can easily suppose matter (considered as inert) without the property of distant mutual attraction, or gravitation; this last property may be fairly viewed as added to, or superinduced upon mere inertia. Nor can we call the

two either cause and effect, or effects of a common cause; our knowledge does not entitle us to make either supposition. We can prove cause and effect only by exhibiting first a cause, and then an effect flowing from it. Here the two facts or properties are inseparable.

There is no other equally unambiguous instance of a law of universal co-existence. The examples above quoted with reference to three properties—specific gravity in the gaseous state, atomic weight, and specific heat—may, for anything we know, be mutually implicated, or related as cause and effect. If we understood more thoroughly the ultimate arrangement of the atoms of bodies, and their intestine motions, we might not improbably find that some one fundamental property was at the foundation of all the three;—a real essence, of which these are but *propria*. As regards many of the minor laws, the existence of either implication or causation is more than a mere surmise.

Under such circumstances we are entitled to conclude that uniformities of general co-existence are very rare. The presumption or probability (although not the certainty) in every new case of uniformity is that it is a case of causation and not of co-existence. Thus, the conjunction of Mind and Body may be a co-existence independent of causation, like inertia and gravity; but it may also follow the more prevailing type, and be a case of cause and effect. Which is cause and which effect, or whether they are effects of a common cause, may be open to dispute.

5. The only proof of Uniformities of Co-existence not known to depend on causation, is uncontradicted Agreement through all nature.

This is the proof of the Law of Causation itself. Now any uniformity not coming under causation must stand on its own independent evidence; and this evidence is uniform agreement throughout the whole compass of observation. We must find it true in all times, all places, and all circumstances; and provided our search has been so extensive, that if there were any exceptions we should light upon them, and no exceptions have been found, we are entitled to declare it a law of all nature.

The coincidence of gravity with inertia has been proved over the entire globe; it applies undoubtedly to the solar system; and by very strong analogy to the distant stars. This, therefore, may be held to be an established uniformity of co-existence.

The alliance of mind with a bodily mechanism extends throughout the whole of animal life, past and present.

The co-existences above mentioned regarding the properties of gaseous specific gravity, atomic weight, and specific heat, have to be verified by the method of Agreement throughout all bodies. We cannot, as in cause and effect, presume from a small number to all the rest.

6. The special coincidences making up the Natural Kinds must also be verified by Agreement over the whole field of instances.

We have already remarked that an exception to a kind, arising from the failure of an essential property, would not be the infringement of a uniformity, but the setting up of a new kind. The only case for proving a co-existence would be the case of *concomitant* properties, or those not adopted into the essence or connotation of the kind. Of such a character is the blackness of the crow, the whiteness of the swan, and variations of colour generally; a point seldom treated as essential, whether in minerals, plants, or animals. Now the sole proof that 'every crow is black,' is observation through all Nature; so long as no other colour is seen, we affirm the general proposition; the occurrence of various *albinos* has disproved the generality, and reduced it to an approximate generalization, of a very high order of probability.

CHAPTER IV.

LAW OF CAUSATION.

1. The Uniformities of Succession presented in nature are subject to one great uniformity—the law of Causation.

The law may be expressed thus:—In every change, there is a uniformity of connexion between the antecedents and the consequents.

No single expression sums up all that is implied in Cause and Effect. When it is said, 'Every effect has a cause, and every cause an effect, and that the sequence is regular, the same causes being always followed by the same effects,' the

proposition is an identical statement; the word 'Cause' means what brings about an effect; and the word 'Effect,' what follows from a cause. To avoid this objection, we may state the law as follows :—'Every event that happens is definitely and uniformly connected with some prior event, or events, which happening, it happens; and which failing, it fails.' The kindling of a fire follows regularly on the prior events of making a heap of combustibles and applying a light.

A law is more sharply stated by help of its denials. Causation denies two things. First, it denies pure spontaneity of commencement. If the law is true, no change arises out of vacuity or stillness; there must be some prior event, change, or movement, as a *sine quâ non* of the occurrence of any new event. A fire never bursts out without some commencing circumstance, in the shape of movement, change, or activity.

Secondly. The law denies that events follow one another irregularly, indiscriminately, or capriciously. The same circumstances that make a fire burst out to-day, will, if repeated, make it burst out to-morrow, or at any future time. The same pain, in the same circumstances, does not at one time repel, and at another, attract and allure us. In short, the law is the statement of *uniformity* in the Succession of events.

2. In Causation, the same cause always produces the same effect; but the converse does not hold; the same effect is not always produced by the same cause. There may be Plurality of Causes.

A severe blow on a man's head will always cause death: but death is not always caused by a blow on the head. There are many causes of motion; and the presence of any one in the proper circumstances, will always be followed by motion.

This is an important limitation of the law, and has to be kept in view in the investigation of causes. If a change has occurred, there must have been a previous change, or antecedent fact, but not necessarily one particular antecedent.

3. The Plurality of Causes is subject to uniformity in two respects: (1) the number of causes is fixed; (2) the character of each is as definite as if it were the sole cause.

The causes of death may be numerous, but they are all fixed and knowable; and, when known, may be counted on with certainty and precision. The fact of plurality renders the causation of an event ambiguous; there may be several alternative antecedents. Yet, these antecedents being, once

for all, exhaustively known, we are sure that one of them is the operative circumstance in the case before us.

It will be pointed out afterwards that plurality of causes is more an incident of our imperfect knowledge than a fact in the nature of things. As knowledge extends, we find less of plurality. The numerous apparent causes of motion are different only in superficial appearance; they are all one at bottom.

4. Causation may be viewed under three different aspects.

(1) The first may be called the *practical* and popular aspect —a partial view suited to the ordinary emergencies of life. Under this aspect, the cause is some one circumstance or condition demanding our solicitude, as being precarious. Thus, when the soldier, on the eve of an engagement, is urged to keep his powder dry, this is not the whole cause of his hitting the enemy; it is the circumstance that happens to be in peril at the time.

(2) The second aspect is the Scientific or complete view of Causation. Under this view, all the conditions or antecedent circumstances are fully enumerated.

(3) A third aspect is Causation viewed as embracing the modern generalization, entitled the Conservation or Correlation of Force.

CAUSATION PRACTICALLY VIEWED.

5. In common language, the Cause of an event is some one circumstance selected from the assemblage of conditions, as being practically the turning point at the moment.

A man slips his foot on a ladder, falls, and is killed. The cause of the fatality is said to be the slipping; for if this one circumstance had been prevented, the effect would not have happened. Yet, in order to the result, many other conditions were necessary:—the weight of the body (gravity), the height of the position (a certain collocation), the fragility of the human frame. Yet, for practical purposes, we leave out of sight at the moment all the elements that are independent of us and secure, taking notice only of what is in our power and needs our attention. By a common ellipsis, all arrangements that are fixed and settled, are passed over in silence. We presume on the forces of heat and gravity, and devote our care to the choice and shaping of the materials whereby these forces may be made to work out our ends.

When we speak of food as the cause of animal strength, we

suppose a healthy constitution, able to digest and assimilate it. But, in this particular case, mankind long erred in ignorantly suppressing a condition no less essential than food, namely, the oxygen of the atmosphere — the aerial element of our food.*

Language is adapted principally to this mode of viewing causation. In the distinction of agent and thing acted on, which pervades the whole of grammar, and gives the character to the active verb, there is an arbitrary selection of one circumstance as cause, other equally indispensable circumstances being overlooked. A prize ox is reared in a breed of cattle; the breeder is by courtesy styled the cause or agent; but his activity is only a single, although indispensable circumstance. A teacher instructs a pupil, and is credited as the cause or author of the pupil's knowledge. A still more glaring ellipsis is practised in attributing the issue of a war to the commander-in-chief; as when we speak of the conquests of Alexander or Cæsar. 'The monk that shook the world' is rhetoric for the agency of Luther.

The first attempt at a precise analysis of Causation was made by Aristotle. He enumerates *four* kinds of Causes,—the *material*, the *formal*, the *efficient*, and the *final*. The *material* cause is literally the matter used in any construction; marble or bronze is the material of a statue. The *formal* cause is the form, type, or pattern in the mind of the workman; as, the idea or design conceived by the statuary. The formal cause of a building is the architect's plan. The *efficient* cause is the power acting to produce the work, the manual energy and skill of the workman, or the mechanical prime mover, whether human power, wind, water, or steam. The *final* cause is the end, or motive on whose account the work is produced — the subsistence, profit, or pleasure of the artificer.

Aristotle gives the instance of a physician curing himself, as combining all the four causes in one subject.

* Whenever the existence or safety of anything depends upon a *sum* or *system* of contrivances adapted to a common end—which, together, are conditions necessary for its preservation—then the destruction, disturbance, or removal of one of these contrivances—the failure of any part of this composite system of safeguards—is considered as the *cause* of the ruin of the whole. For example, if the action of any one of the functions or organs necessary to human life is stopped, life is extinguished, and the circumstance producing that effect is said to be the cause of death. So, if a ship springs a leak and sinks, or if an army is surprised through the absence of a sentinel from his post— the springing of the leak, and the absence of the sentinel, is said to be the cause of the loss of the ship and the surprise of the army. The language by which such an effect is commonly ascribed to a merely negative cause is elliptical. (G. C. Lewis).

This analysis is obviously taken from human industry, which contains the several circumstances mentioned. It throws no light upon causation in the order of nature; while the attempts to express natural phenomena according to such a scheme, have led to distortions and unmeaning conceptions.

The first and second causes give the celebrated distinction of Matter and Form, which pervades the whole of Aristotle's philosophy. The third, the Efficient, has continued in the language of science; a better designation for the meaning is Prime Mover, or Moving Power. The fourth, the Final cause, is more perspicuously expressed by Motive, End, Intention, Purpose, Object or Design; it applies to nature only as personified, or as the work of a personality.

SCIENTIFIC CAUSATION.

6. In scientific investigations, the Cause must be regarded as the entire aggregate of conditions or circumstances requisite to the effect.

All the conditions suppressed by the practical man are brought back by the scientific man in a full statement of the cause. If any are omitted, it is because they are so obvious that no person could overlook them. There is a legitimate ellipsis of expression, even in the scientific enumeration of conditions.

The cause of the inundations of the Nile would be described as (1) the fall of moisture as snow on the lofty mountains of Africa where the Nile has its source; (2) the melting of this snow by the summer heat. Gravity, the laws of heat, the constitution of water, are all a part of the cause, and if not mentioned, are supposed to be fully present to the mind of the hearer.

The growth of plants is a complicated causation. There must concur, the properties of the germ, the contact with the soil, air, water, saline bodies in the soil, heat, light, &c. The agriculturist thinks only of a select number of these—the seed, the quality of the soil, moisture, and heat; the vegetable physiologist brings into view the physical, chemical, and vital agencies, which are the causes of the phenomenon in the final analysis.

The cause of vision is summarily given as light entering the lenses of the eye. The full enumeration of the circumstances would include the optical action of the lenses, the physiology of the coats of the eye, and of the nerves and brain; and finally, the link associating a certain activity of the brain with a feeling in the mind.

The cause of the Reformation was Luther's preaching against the sale of indulgences, concurring with the administration of the church, and the state of men's minds at the time.

In speaking of antecedents of the French Revolution, it is customary to use the plural—Causes; signifying that a union of many circumstances or conditions was involved. In the enumeration of Alison, no less than *sixteen* causes are given.

Gibbon attributes the rapid growth of Christianity to one primary cause, namely, the convincing evidence of the doctrine, and of the ruling providence of its author; and to five aiding secondary causes, 'which assisted in producing the effect, viz.: 1, the inflexible zeal of the early Christians; 2, the doctrine of a future life, as held by the Christian Church; 3, the miraculous powers ascribed to the primitive church; 4, the pure and austere morals of the Christians; 5, the union and discipline of the Christian republic.'

The conditions of phenomena include *negative* as well as positive circumstances; the absence of hindrances to the operation of the agents concerned. The sun is the cause of vision, provided he is not screened, provided the subject is not asleep or blind. It is usual to suppress the mention of all such hindrances, if they are really absent.

7. The suppressing of essential conditions is a common fallacy of Causation.

When, in the statement of a cause, there is not merely an ellipsis of understood circumstances, but an omission of some essential fact, the consequence is positive error.

When the healthy effect of residence at a medicinal spa is attributed exclusively to the operation of the waters, there is a fallacy of causation; the whole circumstances and situation being the cause.

This is a common form of Inductive fallacy, and prevails in all the complicated sciences, as Politics and Medicine.

CAUSATION AS CONSERVATION OF FORCE OR ENERGY.

8. A great advance, in the mode of viewing Causation, is made by the modern discovery of the law named 'Correlation of Force,' or 'Conservation of Energy.'

The great generalization of recent times, variously designated the Conservation, Persistence, Correlation, Convertibility, Equivalence, Indestructibility of *Energy*, is the highest expression of Cause and Effect. In every instance of causation, there

is a putting forth of force in given circumstances, and the law in question states exactly what becomes of the force, and is often the sufficing explanation of the special phenomena, as well as the embodiment of nature's uniformity in successions.

Statement of the Law of Conservation.

9. Force, Energy, Moving Power, or Work Power, is embodied in various forms, all mutually convertible at a definite (fixed) rate. The extinction of energy in one form is accompanied by the creation of energy in another form: in the transmutation *work* is said to be done, and no force is absolutely lost.

(1) *Matter in motion* is Force manifested as actual, apparent, or *kinetic* energy; but the modes of motion may be very various. We are most familiar with that of mechanical energy, as in the case of a flying-ball, a water stream, or the wind. There is, however, reason to believe that the forces named heat, light, and electricity, consist in minute movements of material particles.

Matter in position corresponds to a possible production of power; or the configuration of a material system corresponds, in virtue of the mutual action of its parts, to a definite amount of *possible* or *potential energy*. A head of water represents a certain amount of moving power *by its very position*. This energy may not be evoked, and may exist for ever only as potential. Yet it is as really existing as when it is employed to turn a wheel.

(2) The different forms of energy may, under certain arrangements, be transmuted one into the other. Mechanical force may pass into heat, and heat into mechanical force: an energy of motion may be exchanged for an energy of position and conversly. The rate of exchange is invariable.

(3) In the interchange of energies *nothing is lost*. In every case where energy disappears by resistance, and is seemingly lost, a definite equivalent of *heat* is generated.

If we suppose a portion of the universe isolated so that it neither gives nor receives energy from without, then the principle of the Conservation of Energy asserts that the sum of the kinetic and potential energies within this material system is constant and unalterable. The actions and reactions of its parts can only vary the *relative proportions* of kinetic and potential energies, but not their *amount*.

Of these three circumstances the first, matter in motion or in position, is the definition or generalisation of force or energy;

the second, transmutation of one form of power into another; and the third, conservation of the sum of the energies of motion and position of any self-contained system, under all changes, are the properties or *predicates*, constituting the Law of Correlation or the Conservation of Energy.

10. In explaining the principle of Conservation as applied to the different forms of actual energy, we may rank them in two divisions, MOLAR and MOLECULAR,—motion in *mass* and motion in *molecule*.

The Molar Forces are the same as those termed *Mechanical*.

The molar or mechanical forces are the motions of sensible masses, as a hammer, a waterfall, a locomotive, a planet. The science of Mechanics, or Molar Physics, is occupied with the computation of these forces, in their transfer and re-distribution under all varieties of circumstances.

The Persistence or Conservation of Force was first distinctly conceived with reference to these palpable motions. Newton's First Law of Motion expresses the fact that a mass once in motion will, if unobstructed, always continue in motion at the same rate; which is the same as saying that force never decays. In free space, beyond the reach of molestation from without, a moving body would preserve its motion for ever. This is the simplest aspect of Conservation.

A moving body *encountering a second body*, whether at rest or already in motion—(1) if we suppose both bodies to be perfectly elastic—imparts its own motion, in whole or in part, to the body struck. This is a new situation. There is a loss of power on one side, and a gain on the other; a redistribution of the movements of the two masses. Now, in this state of things, the Law of Conservation declares that in the interchange nothing is wasted; whatever the striking body loses, the struck body gains.

If the two masses are equal, there will be simply an interchange of velocities, and of momenta; and if they are not equal, still the impact will not alter either the total momentum, or the moving energy of the whole.

(2) When the bodies are inelastic, then the visible energy will disappear in whole or in part. If a contemporary of Newton had been asked what becomes of the force of cannon shot arrested by a dead wall, he would probably have answered that an infinitesimally small movement was imparted to the

mass of rock and its contiguous material. This would have been regarded as a consistent following out of the theory of conservation in communicated momentum. The lost energy of the quick-moving ball would exist as energy in a huge mass very slowly moving.

Had the farther question been asked—what becomes of the force of two opposing movements destroying one another—the above answer would not have served the purpose. No motion is created in any form; there is nothing to appearance but sheer waste on both sides.

The new difficulty would in all likelihood have been met by a very plausible assumptiom. It might have been said that the conservation of force was to be interpreted as force operating *in the same direction;* all forces in the opposite direction being held as negative quantities, like debt to credit. It would be a sufficient account of any force that it had neutralized an equal and opposing motive force; as when a payment of a hundred pounds to any one's credit extinguishes a hundred pounds of debt.

Yet this explanation is fallacious as a principle, and in opposition to the facts of the case. Two bodies moving in opposing directions are not to be compared to positive and negative; each has a positive value, for any purpose whatsoever. Two streams running in opposite directions, are as good for mill-power as two streams moving in the same direction. Easy mechanical contrivances can, without loss, divert a moving power into any direction. The two opposing forces that by collision extinguish one another, could by a suitable arrangement, unite their power in the same course. The destruction, therefore, that ensues in a hostile collision, is (on the present assumption) pure destruction, unredeemed waste, annihilation. It is at variance with the Law of Conservation, which would have to be restricted and qualified to moving bodies always following the same course.

The principle of Conservation has been rescued from this perplexity by the discoveries of recent times. If two inelastic bodies encounter and arrest one another's movements, the mechanical or molar energy is indeed sunk; but re-appears in an equivalent energy communicated to the molecules, and manifested as *Heat.* The molecular motion excited in the encountering masses is exactly equal to the molar energy consumed. This is an entirely new view of Force; and saves the principle of Conservation, by giving it an enlarged scope. It teaches us to take account of all the

protean transformations of energy, and prevents us from rashly declaring that force is destroyed when it has ceased to appear in the original shape. Mechanical force in some circumstances, well understood, yields mechanical force; in other circumstances, for example, hostile collision, it yields a molecular force, namely, Heat.

Going back upon the first query propounded to a contemporary of Newton, — the account to be given of a ball's impinging on a dead rock,—we should now answer the question not by mechanical transference—a slow motion imparted to the rock—but by molecular transformation. The ball and the place where it struck would both be found to rise in temperature, and the more as the moving force of the ball was greater. All the energy would be accounted for in this way. In every case of collision, and even of impact without opposition, something is lost by conversion into heat. The loss of power by *friction* is a generation of heat.

11. The Molecular Forces may be provisionally enumerated as follows :—(1) Heat, (2) Chemical Force, (3) Electricity, (4) Nerve Force, (5) Light.

This enumeration is to be held as provisional; it may not include all the species; and it may represent, as distinct kinds, what are only slight modifications of one kind.

(1) *Heat*.—Probably the best example for showing the molecular forces, in their contrast to the molar, or mechanical, is Heat. Our experience of this influence is abundant and various. Yet, only of late years have we been led to call it a form of moving matter, a species of molecular motion or vibration, which bursts forth on the shock that extinguishes a mechanical impetus.

Such shocks of mechanical collision are the usual mode of transmuting mechanical energy into heat. Friction is only a more gradual and protracted collision. A familiar illustration is seen in hammering a piece of cold iron till it becomes red hot. The high temperature of the sun is hypothetically accounted for by collisions of enormous swift-moving masses, brought together by gravity.

Such is the situation for converting mechanical motion into Heat. The transmutation of heat into Mechanical force, is effected through the expansion of bulk caused by raising the temperature of bodies. In solids, and in liquids, this expansion is small in range, but great in force; and is adapted only to special cases, as the splitting of rocks, where

there is need for a great power moving only a very little way. Through the medium of gases, the expansion can be converted into mechanical energy, in any form we please, as in the diversified performances of steam power.

In generating mechanical power by heat, as in the steam engine, the *source* of heat must be of a higher temperature than the *medium;* the fire must be hotter than the water and the steam. The power is given forth by the descent of the heating body to a lower temperature. Between bodies equally hot, there is no development of mechanical power, no forcible expansion of any one body.

There is a peculiar incontinence attaching to the Heat force. We usually find that some body possesses it in such superior degree as leads to radiation upon other bodies, with loss to the radiating body. This is the moment for obtaining a mechanical or other equivalent. It is also the moment of *dissipation of energy* without equivalent, if the opportunity is not turned to account. The solar heat falling on the planets gives an equivalent in raising their temperature, and in producing other forces; what is not intercepted is at once dissipated into empty space, without farther result than to elevate by a slight addition the general temperature of space; a real but unavailable equivalent of the heat lost to the sun.

It is as regards Heat that the rate of exchange with mechanical force has been settled with the highest numerical precision. The assumed unit of mechanical energy is the foot-pound of England (and the metre-kilogramme of the Continent), meaning the force expended in raising one pound weight one foot. The unit of heat is defined as the amount that must pass to one pound of water in order to raise its temperature (or sensible heat motion) by one degree of the thermometer. The rate of exchange or equivalence is 772 foot-pounds to one pound of water raised 1° Fahrenheit; or 1390 foot-pounds to 1° Centigrade. In the Continental scale of weights and measures, the expression is 425 metre-kilogrammes to one kilogramme of water raised 1° Centigrade. By a perfect machinery of conversion of heat into mechanical power, the heat requisite to boil a gallon (ten pounds) of freezing water would lift 1389600 pounds one foot.

(2) *Chemical Force.*—Energy, in a form adapted to separate chemical compounds, and as it appears when bodies combine chemically, is chemical force. When water is decomposed into its elements—oxygen and hydrogen—a certain amount of force is

absorbed or used up in order to bring about the decomposition; and the same force reappears when the elements are re-combined.

This chemical force is a very slight modification of Heat. In the case of combination, the force evolved appears as heat in its common form. Indeed, our artificial heat of combustion, is the chemical force liberated in the chemical combination of oxygen and carbon (supposing coal or charcoal to be the fuel). By peculiar arrangements, this force of combination may be prevented from appearing as sensible heat, and may take other forms; it may decompose other compounds (as in the double decomposition of salts); or it may pass into electricity or into magnetism.

Again, Heat may operate as a *decomposing* agent. Many compounds are decomposed at once by the application of heat, as the oxides of the noble metals. A familiar example is the decomposition of chalk or carbonate of lime, in a lime kiln; the heat drives off the carbonic acid, and what remains is burnt lime. Other compounds are decomposed by heat, when there is an arrangement for combining one of the decomposed elements with a third substance; as when water is decomposed in a red-hot iron tube, the oxygen combining with the iron.

That heat, the result of combination, should be the means of decomposition, is the proper, the natural consequence of the Law of Conservation. Whatever is given out when elements combine, must be restored when they separate again. This is the exact relationship of heat to chemical action, which is disguised and apparently reversed by the familiar employment of heat *to make bodies combine*, as in lighting a fire. The application of heat in such a case, however, is a mere incident; it seems to operate by disturbing the quiescence of the elements. It no more renders heat a combining power, than the pailful of water thrown into a pump before pumping is the cause of the subsequent flow.

The rate of commutation of Heat and Chemical Force, has to be given in the detail, inasmuch as different compounds give forth different quantities. I quote as examples a few oxygen compounds. One pound of *hydrogen* burnt (that is, combined with oxygen) would elevate, by 1° C., about *thirty-four thousand pounds of water*. This is the most heating of all oxygen combinations; we have long been familiar with the intense heat of the oxy-hydrogen blow-pipe. Of simple bodies burnt, or combined with oxygen, the next in rank, is

carbon, the chief ingredient of ordinary combustion, and also of animal combustion. The figure for carbon is less than one fourth the figure for hydrogen; a pound of carbon burnt elevates, by 1° C., about *eight thousand* pounds of water. Phosphorus ranks next among the simple bodies examined (5747 pounds); then sulphur (2307); the metals, zinc, iron, and tin, are nearly equal (zinc, 1301, iron, 1576, tin, 1233).

(3) *Electricity*.—This variety of molecular force is distinguished by two main peculiarities. The first is *polarity*, or the development of opposite forces at opposite points; the magnet is the most familiar example of the power, operating in masses of matter. The second is named *conduction*, and means the rapid transmission of the force from one part of a body to another, along a wire, for example; a process of conveyance quite different from any of the modes of the transmission of heat. An electrical charge passes almost instantaneously, and with little diminution of force, through miles of copper wire.

The name 'Electricity' now includes various phenomena marked by characters widely different. Three types or species may be indicated—Magnetism, Friction or Franklinic Electricity, and Voltaic Electricity: all these have a molar as well as a purely molecular side, the last is in close relation to chemical force. *Magnetism*, as a member of the group of Correlated Forces, under the Law of Conservation, is best studied in the form called Electro-magnetism, or magnetism generated from electricity; for, while the magnetism, which is a mechanical attraction, can be estimated by its mechanical effects, the electricity can be estimated chemically by the amount of acid and zinc combined in the cells of the battery. *Friction Electricity*, in the common electrical machine, is generated by mechanical force (sometimes by heat, as in crystals); its discharge, being marked by vehemence, concentration, or *intensity*, is not measurable with accuracy; the effects are seen in the rupture of atomic cohesions, in strong outbursts of heat and light, and other indications of concentrated force. *Voltaic Electricity* is the species most closely allied with Chemical Force; which force is its source, its measure, and one of its results. Through chemical force, as measured by the amount of material chemically combined in the voltaic cells, we can state the rate of exchange or commutation of Voltaic Electricity with Mechanical force, and with Heat.

These three modes of Force—Heat, Chemical force, Electricity—are the well-defined species of molecular activity;

they can all be measured and put into strict equivalence with Mechanical Energy. There still remain, however, Light, and any modes of activity in living bodies, distinct from, and superadded to the forces of the inorganic world; the Nerve Force is one well-marked example. From the close analogies between this last-named force and Electricity, we may take it next in order.

(4) *Nerve Force.*—The Nerve Force is the special activity of the nerves and brain. Like Electricity, it is a current force. It differs from Electricity in moving at a comparatively slow rate; and also in depending for its maintenance upon chemical combinations in the material of the nerves; hence, while electricity decreases as it goes, the nerve force increases. Although this force cannot be subjected to accurate measurement, we conclude from analogy that there is an exact equivalence between it and the chemical transformations that are its source; part of the food of the body is expended in supplying it. It contributes to muscular power, in which case it has a mechanical equivalent; and to molecular changes, chemical or other, also on a definite rate. As the physical concomitant of mental states, we must still regard it as definitely related in quantity to these; a double amount of feeling, other things being the same, involves a double amount of nervous transformation.

(5) *Light.*—The divorcing of Light from Heat, in the enumeration of the molecular forces, needs to be explicitly justified. The divorce is at best provisional and temporary; the reasons are such as the following. Although Light is a distinct *product* of the other forces, more especially Heat, and is instrumental in *causing* at least one of them, Chemical force, yet hitherto nothing has been done towards establishing the rate of commutation or exchange between it and the others. When a body is heated till it becomes luminous, there ought to be a definite loss of heat, equivalent, on a certain scale, to the light produced; at present, however, we have made no approach to such an estimate. Moreover, although light is the instigator of chemical change, we cannot say that it operates by supplying chemical power, as heat or as electricity does; the effect may be similar to the action of heat in lighting a fire, a mere disturbance sufficing to begin the chemical union of elements ready to combine. Chlorine and hydrogen, mixed together, will not combine chemically in the dark; the combination begins under the light. It is to be remarked, however, that *decomposition* is the direct test of chemical force. Now, light will not cause decomposition unless in the presence

of a body, like hydrogen or chlorine, having a powerful tendency to combine; or, when, as in vegetation, light is accompanied by heat. We are, therefore, led to regard light chiefly as the *prompter* to a change otherwise maintained. And in this view there is a numerical proportion between the amount of light and the extent of the chemical action; as shown in the researches of Bunsen and Roscoe (*Phil. Trans.*, 1857).

When mechanical force operates against gravity, as when a projectile is thrown upwards, the force is at last spent; the equivalent gained is *a position of advantage*, with respect to gravity; for, by the continued operation of the gravitating energy, the whole of the impetus lost will be restored in the downward direction (the resistance of the air being left out of the account). We are familiar with this employment of gravity in clocks propelled by weights regularly wound up to a height. To this peculiar situation, Prof. Rankine has applied the name '*potential* energy,' to distinguish it from the energy of a mass in actual motion. The placing asunder of the celestial bodies, all which gravitate towards each other, was the primeval situation of advantage, whence may have arisen (by collisions) the heat of our suns and planets, and by consequence all the other modes of force—mechanical, chemical, and electrical.

It is by this operation that the force of gravity is introduced into the circle of forces, and is counted as a cause or productive agent. Viewed in itself, it creates no force; what is gained in visible force is lost in position; to restore the position would require the power to be given back. It can, however, divert power; it can also store up and re-distribute it, as a banker does money.

A similar position of advantage may be found in the molecular forces. Thus, the existence of two elementary bodies, able to combine, is a potential *chemical* energy, which, on the occurrence of the opportunity and the stimulus, is converted into actual molecular energy. Such is the potential force of our coal, and of all the uncombined and combinable elements of the globe,—as native sulphur, the native metals, and the lower compounds susceptible of entering into higher compounds

The molecular attractions of bodies (as cohesion) may operate exactly in the manner of gravity. A spring is an obvious example. The elasticity of compressed air may be turned to the same account.

12. Causation, viewed as Conservation, is thus the transferring or re-embodying of a definite amount of Force.

When a ship is propelled by wind or by steam, the motion is said to be caused by those agents; which expend themselves in producing the effect. The expansiveness of steam is due to heat operating through the medium of water. The heat arises from the combustion or chemical union of coal and oxygen. The coal was the carbon of plants of former ages, whose growth demanded an expenditure of solar heat.

So, again, in the human body, mechanical force is obtained by mucsular exertion; that exertion is owing to the oxidation of the materials found in the blood; these materials are either vegetable products, or the bodies of other animals fed on vegetables; and, thus we come round again to the agency of the solar ray in vegetation.

Transferred energy is thus the final and sufficing explanation of all change, and the only explanation in the highest sense of the word. Any fact of causation not carried up into this supreme law, may be correctly stated, but it is not accounted for.

Whatever appearances militate against the principle of Conservation are to be held as fallacious. The 'perpetual motion' has long been rejected as incompatible with the mere mechanical phase of the principle. There still remain to be removed various errors against the more comprehensive view. For example, the incautious remark is frequently made that *Light* is the operative cause of vegetative growth, meaning light alone; but the large amount of chemical power required to decompose water into its elements (the bodies of all others most costly in their demands) could be furnished only by the heating rays of the sun; however much light may co-operate in giving stimulus or direction.

13 The Law of Conservation exhausts Causation, viewed as the transfer of Force or Moving Power, but leaves many complicated, and, as yet, unsolved questions of COLLOCATION.

If we view causation as the transfer or re-distribution of a certain definite amount of moving power, nothing can be simpler than the statement of the principle; and, in many instances, we find it easy to make the exact calculation. But the circumstances attending the transfer, the situation or *collocation* of the materials engaged, may have all degrees of complexity.

The simplest situation is the transfer of mechanical power by impact, as when a golf ball is impelled by the momentum of the club At least, we usually suppose this to be a simple case; we take no account of the internal agitations of the particles of the body struck, being content to assume that the momentum is transferred with inconsiderable loss. Here, then, the collocation is the easiest possible; it is the sensible contact of one moving body with another, either at rest or already in motion. Even when one moving body strikes another moving in a different direction, the difficulty of the collocation is not much increased; the mechanical theorems of oblique forces will predict the new distribution, and assign the directions after the impact.

When we pass from the interchange of mechanical forces, to the mutual interchange of mechanical and molecular, we encounter situations or collocations of various degrees of complexity. Least difficult is the relation of mechanical energy to heat. When a moving body encounters a dead resistance, the whole of the energy is resolved into molecular motion of the encountering masses; if the body struck gives way in part, and takes on motion, the actual energy generated is so much deducted from the energy transformed into heat.

The transfer of heat into mechanical force, as in the steam engine, is accomplished by the expansiveness of the heated matter. Starting from the fact of forcible expansion, the conversion is merely an instance of mechanical impact. The difficulties are postponed to the next stage.

The interchange of Heat and Chemical Force, the production of each from the other, at will, is effected by an arrangement that can be expressed with considerable definiteness in the gross, although leaving the ultimate links of transition in deep obscurity. The active combination of two combinable bodies, as carbon and oxygen, evolves heat; but the minute circumstances of the evolution can be only *hypothetically* surmised. The intestine heat motions of carbon and of oxygen, in their separation, when transferred to the joint carbonic acid molecules, are in excess, and the surplus gives elevation of temperature, or sensible heat, to the mass.

The re-conversion of Heat into Chemical Force (potential), as in chemical decompositions, is somewhat more complicated, but an account can be given of the situation in gross. In the cases where decomposition is effected by heat alone, we have the simple restoring of the surplus heat of the combination. In the other cases, where a new combination must be formed,

we have an additional circumstance, still perfectly definable, and, in a rough manner, hypothetically conceivable.

The difficulties of Collocation grow thick upon us when we grapple with the Electrical group of forces. The *polarized* state of matter, whether in mass, as the magnet and the Leyden jar, or in molecule, as in the decomposing cells of the voltaic battery, is a new and unique phenomenon; and its generation by mechanical force or by heat may be stated in the extreme terms, but without intermediate explanation, even by a plausible hypothesis. After many laborious tentatives, Faraday discovered the arrangement for directly converting mechanical power into voltaic electricity (commonly called the magneto-electric machine), but the links of the transition or intermediate molecular changes are as yet unassignable.

Yet worse perplexities surround the collocations for transferring force in Living Bodies. Even the simplest case—the production of Animal Heat from chemical combination or combustion—is anomalous when compared with the same phenomenon out of the body. The general fact is oxidation, but the circumstances and arrangements are peculiar and unknown. Again, the production of Muscular Force from the process of oxidation is in accordance with the Law of Conservation, while the transition links are hitherto inscrutable. Likewise, the Nerve Force has the same common origin in chemical transformations (or closely allied molecular transformations) as the other forces, and follows a regular rule of exchange, while the mode of derivation is involved in obscurity.

14. Seeing that, in Causation, there must be provided, not merely a sufficient force, energy, or moving power, but also the suitable arrangement for making the transfer as required; this completing arrangement, or *collocation*, is a part of the Cause, and (by ellipsis) is frequently spoken of and investigated as *the* Cause.

A running stream is the proper source of the energy that turns a mill. In order to the effect, however, the due collocation or connexion must be made for bringing the water to bear upon the machinery. Hence, the stream being taken for granted, the cause of the grinding of the corn is the providing of machinery, and the regulation of the sluices; which circumstances are of the character, not of force, but of collocation.

So, in a Voltaic Battery, intended to decompose water, or to excite an electro-magnet, the prime mover is chemical force arising in the cells of the battery; the completing

arrangements include the whole apparatus of the battery, and the final act of closing the circuit.

The combination of the food materials with the oxygen of the air, may be reckoned the source of all animal power; but so numerous are the conditions to be secured in the way of arrangement or due collocation, that we have often to think far more of these than of the propelling agency derived from the primal source of all moving power. We not unfrequently assign as the cause of a man's bodily strength, a good digestion, healthy lungs, or a good constitution generally, and say nothing of the real derivation of the strength; the reason being that, without the complex group of arrangements implied in these facts, the power would not be transferred from the common fund and embodied in the man's muscular and nervous energies.

When a man properly supplied with food, goes through a day's work, we recognize a transfer of moving power, under the Law of Conservation. When any one prostrate with weakness is restored to strength by a few drops of laudanum, there is no proportion between the cause and the effect, considered as moving power giving birth to equal, although different moving power. The salutary interference must be regarded, not as a communication of moving energy corresponding to the access of energy that follows, but as the restoring of some *arrangement or collocation, necessary to the* conversion of the body's nourishment into the various forces of animal life.

As our knowledge of the Law of Conservation is such as to account for the remote source of all power whatsoever, the enquiry usually presented for scientific investigation is by what arrangements a given effect has been secured, or through what media the bank of Nature's Force has been drawn upon in the particular instance. Not many years ago the phenomenon of volcanoes was regarded as wholly mysterious; since the establishment of the Law of Conservation, all that part of the mystery connected with the source of the upheaving power has been removed. It is the internal heat of the earth converted at certain points into mechanical energy. What remains for scientific investigation is a pure question of collocation; we are still ignorant of the arrangements for effecting the transference of power in that particular manner.

In the same way, all the great cosmical changes, marking the evolution of the solar system, and the geological history of the earth, are referable to the primal sources of energy; the

moving power at work is no longer a secret. Yet the circumstances, arrangements, or collocations, whereby the power operated to produce our existing mountain chains, the rise and fall of continents, the fluctuations of climate, and all the other phenomena revealed by a geological examination of the earth, are as yet in uncertainty.

15. The importance of Collocation appears in another aspect, as representing the modes of Potential Energy.

Potential Energy is energy of situation, arrangement, or collocation. The Potential Energy, stored up when moving bodies work against gravity, till their force is exhausted, is described as *a position of advantage*, a collocation of power, with reference to a gravitating mass. Here we have the remarkable case of force embodied in absolute stillness or quiescence. A mountain tarn is absolutely quiescent while its enclosure is perfect; the immense impetus to be displayed in its descent to the plains is not at present represented even by molecular motion.

A similar energy of collocation is created when bodies are distended in opposition to their cohesive attractions, as in springs.

Lastly, there is the energy of separation of Chemical elements, as in coal, sulphur, metals, and other combinable substances, simple or compound. Gunpowder is a concentration of potential chemical energies, or of combinable elements in a situation of readiness to combine.

It is in the case of these potential energies that we seem to create moving power, to bring forth force, without a prior equivalent force, to make small causes yield great effects. The apparent cause, or antecedent, of a great outburst of moving power, is something altogether trivial, as if force were evoked and absolutely created. Cause and Effect cannot, in such instances, be stated as one moving power transmuted into an equal moving power, molar or molecular. A child's touch might be made to discharge a man-of-war's broadside, or inundate a village. One word of a general, the signature of a sovereign, may destroy an empire.

Cause, in all these instances, has a peculiar and important signification. It is not a moving force equal to the visible energy of the effect, it is the exertion, however easy, that changes a situation of potential energy to a situation of actual energy; the cutting of the string that suspends a weight, the drawing of a sluice, the setting a light to a combustible, the supplying of a motive to human volition.

The course of experimental investigation must adapt itself to this position of our knowledge as regards Causation. We know the ultimate, and, in most instances, the proximate sources of moving power or energy; we know a certain number, more or less, of the conditions or collocations of the transfer; what we still desiderate is the thorough and fully generalized knowledge of the remaining collocations.

In the subtle actions of Light, we are at this moment in doubt whether the luminous ray operates as a dynamical and force-giving agent, like Heat and Electric Force, or only as a collocating agent, either to complete the medium for transmitting a true force, or to convert a potential into an actual force. As causing chemical combinations, we can ascribe to it nothing more than the liberation of the potential chemical energy. So, in acting on the eye to rouse our optical sensibility, it may be no more than a disturber of latent forces.

The settling of this preliminary point is necessary to our progress in the investigations of luminous agency. In merely completing, or else disarranging collocations, Light must exert a dynamical force, but it may be of the very slightest amount, and out of all proportion to the results that ensue. There is no proof that, in any situation, the energies aroused by light are maintained at the cost of the light.

The character of a disturbing agent must attach to many, if not most, of our sensations. The tickling of the nose by the proboscis of a fly cannot be the source of the muscular movements that arise from the feeling. The irritation of a musical discord, the revulsion at an odour, the energetic discharge of a bitter morsel from the mouth—are efficacious as disturbing some collocation, and bringing potential force into actuality.

In the complicated animal framework, there may be violent displays of energy consequent on the withholding of the regular supplies of energy. Extreme hunger may lead to nausea and retching. In the delirium of fever, when no nourishment can be received, there is great muscular exertion. We are at no loss, on the foregoing principles, to solve the apparent contradiction.

16. As Cause may not always mean the Moving Power transferred, according to the Law of Conservation, so, the Effect may not always mean visible energy gained, but a new arrangement or Collocation of materials.

Moving Power is often expended, not with a view to repro-

moving power at work is no longer a secret. Yet the circumstances, arrangements, or collocations, whereby the power operated to produce our existing mountain chains, the rise and fall of continents, the fluctuations of climate, and all the other phenomena revealed by a geological examination of the earth, are as yet in uncertainty.

15. The importance of Collocation appears in another aspect, as representing the modes of Potential Energy.

Potential Energy is energy of situation, arrangement, or collocation. The Potential Energy, stored up when moving bodies work against gravity, till their force is exhausted, is described as *a position of advantage*, a collocation of power, with reference to a gravitating mass. Here we have the remarkable case of force embodied in absolute stillness or quiescence. A mountain tarn is absolutely quiescent while its enclosure is perfect; the immense impetus to be displayed in its descent to the plains is not at present represented even by molecular motion.

A similar energy of collocation is created when bodies are distended in opposition to their cohesive attractions, as in springs.

Lastly, there is the energy of separation of Chemical elements, as in coal, sulphur, metals, and other combinable substances, simple or compound. Gunpowder is a concentration of potential chemical energies, or of combinable elements in a situation of readiness to combine.

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ducing some equivalent power, but merely to re-distribute materials, as in transporting stones from a quarry to erect a building. There is a definite expenditure of power, corresponding to the collective amount of the stones, the distance, and the friction of the roads; but the whole effect consists in a change of position of the materials, without any available energy.

Such is the nature of many Geological changes. When the forces of the earth and the sun raise mountains, they impart a position of advantage, or of potential energy; whereas the transport of erratic boulders, the deposition of strata at a distance from the source of the material, are effects of change without any embodiment of moving power.

17. The evidence for Causation and for Conservation is the same.

This follows from the identity of the principles. Now, as previous to the announcement of the principle of Conservation, a great body of evidence had been accumulated in favour of Causation in the old form, all the experimental proofs in favour of Conservation are a pure addition to the evidence of Causation. In point of fact, however, these experimental proofs are themselves considered adequate to establish the principle of Conservation.

Those speculators that rely on an intuitive basis of proof for this grand generalization treat the two forms as identical. Thus, Sir W. Hamilton is singular among metaphysicians, in giving to the Law of Causation a form almost exactly co-incident with the principle of Conservation, which he may be said to have anticipated.

Mr. Herbert Spencer holds that 'the total quantity of matter in the Universe, cannot really be conceived as diminished, any more than it can be conceived as increased. Our inability to conceive Matter becoming non-existent, is immediately consequent on the very nature of thought. Thought consists in the establishment of relations. There can be no relation established, and therefore no thought framed, when one of the related terms is absent from consciousness. The annihilation of Matter is unthinkable for the same reason that the creation of matter is unthinkable; and its indestructibility thus becomes an *a priori* cognition of the highest order—not one that results from a long-continued registry of experience gradually organized into an irreversible mode of thought: but one that is given in the form of all experiences whatever' (FIRST PRIN-

CIPLES, 2nd edit. p. 175). So much as regards Matter. Now as Matter is known to us merely as exerting force, the reasoning really applies to Force as the underlying experience, the real signification of Matter. Hence, 'by the indestructibility of matter, we really mean the indestructibility of the force with which Matter affects us.'

Without re-entering into the controversy as to the test of truth furnished by the inconceivability of the opposite, we may remark that in the absence of experimental confirmations and interpretations, such an *a priori* conception would be very hazardous to rely on. It would not tell us, for example, that all the force of nature seems tending to a mode of dissipation which is, to all intents and purposes, annihilation, namely, the radiation of heat into space. Moreover, the case has already been adduced of two opposing forces meeting to neutralize one another; a fact formerly accepted as in full consistency with the indestructibility of mechanical force; the universal belief of scientific men, as well as of others, was that nothing survived such a collision. Such *a priori* renderings are of the nature of prophecies made *after* the event.

When the Inductive Methods have been fully explained, the proof of the Law of Causation will be reverted to with a view of indicating its logical character. We here assume it as sufficiently established, and we shall have to proceed upon it deductively in several of the methods of Inductive Proof and Elimination. Without it, there could be no short cut to the establishment of a law of nature; every separate induction would have to be proved by a detailed examination of instances through all nature. The most potent of the Inductive Methods, the Method of Difference, is a deductive carrying out of the law of Causation or of Conservation.

18. The Cause, or aggregate conditions, of an Effect must be sought among the antecedent circumstances conjoined with it.

To appearance, Cause and Effect are a sequence or succession; the cause being first, or the antecedent; the effect, second, or the consequent. It is, therefore, among the circumstances preceding the effect, and in sufficient connexion of time and place, that we look out for the cause.

The main difficulty of the determination is due to the fact that, in most cases, circumstances not entering into the cause are also found among the antecedents, in as close connexion of time and place as the causal conditions. It is to extricate the

real conditions that we must enter on a course of observation, experiment, and comparison of instances.

✓ 19. An *invariable antecedent* is not necessarily the cause or any part of the cause of an effect.

The familiar example is the sequence of day and night; which, although invariable, is not a sequence of cause and effect. So in the evolution of a living being, there are numerous links of invariable succession; and yet we are not entitled, on that circumstance alone, to pronounce the earlier the cause of the later.

The case of day and night, being an understood phenomenon, illustrates the difference between causation, and mere invariability of order. We know that the cause of day, is the light of the sun falling upon the earth; that the cause of night is the absence of the sun. We farther know that the earth's rotation is the circumstance occasioning the periodical absence of the light. The cause of this entire phenomenon is made up of—the luminosity of the sun, our being placed within reach of that luminosity, and the earth's rotation about its axis. The alternation of light and dark is itself but a consequence—a co-effect of the assemblage of facts constituting the phenomenon.

Some of the invariabilities of vegetable and animal growth may be proved, and others presumed, to be only common effects of the real cause.

Such invariabilities are part of the difficulty of causal elimination.

The cause must be an invariable antecedent, but it must farther be what Mr. Mill expresses as the '*unconditional invariable antecedent*,' the sole sufficing circumstance whose presence makes the effect, and whose absence arrests it. Daylight is preceded by darkness; but a state of darkness is not everywhere followed, after a certain duration, with day-light. We cannot, in the case of day and night, separate darkness from its order of alternation with light; but, in referring to other cases, and other situations, we do not find that a present darkness always alternates with illumination.

THE COMPOSITION OF CAUSES.

20. When several motive powers are conjoined, the composite effect is the sum or difference of the separate effects, according as they conspire with, or are opposed to each other.

Causes, understood as prime movers, may be combined, and the result computed by a numerical operation. Two men pulling at the same rope, two locomotives, two weights, when acting in the same direction, have a total effect equal to the sum of the separate effects. When they thwart one another, the result is the difference. For oblique action, the computation is made by the parallelogram of forces.

In the molecular agencies the same rule applies. Two equal fires give twice the heat of one; two bushels of coals make twice the combustion of one, that is, twice the heat; in the steam engine, to double the fuel is to double the motive power. Three identical wax candles produce a triple illumination. Two equal magnets put together will sustain a double weight. If a voltaic battery of ten cells decompose a pound of water in a given time, six similar batteries will decompose six pounds in the same time.

The same principle extends to the Physiological or vital forces. Increase of heat, light, and assimilating material makes a corresponding increase of vegetable growth. Food and oxygen actively combined, give forth a proportionate amount of animal force.

Even in Mind, the ratio holds, although interfered with by new forces arising out of the complication. The pleasures and pains are in accordance with the amount of their several agents. A man's enjoyments increase with his gains and diminish with his losses, other things being the same.

The Social forces in like manner combine, and may be computed by adding the sum of the effects. The addition of new causes of discontent in a people already dissatisfied, makes a corresponding advance towards anarchy and revolution. On the other hand, some agreeable or soothing agency may neutralize an ill feeling already at work.

In all these instances, Cause is to be interpreted as meaning Motive Power, or Force; in no other sense does the rule of arithmetical sum and difference apply. Causes that merely make good the collocation for bringing a prime mover into action, or that release a potential force, do not follow any such rule. One man may direct a gun upon a fort as well as three; two sparks are not more effectual than one in exploding a barrel of gunpowder. In medicine, there is a certain dose that answers the end; and adding to it does no good.

21. Composition of Causes is sometimes applied to Chemical actions, so as to mean not a union of forces, but

the union of substances or materials. In this way, oxygen and hydrogen combine to form water.

This part of the chemical process comes under collocation, and not under force. The mixing of materials, and the union of forces, are not the same fact.

In chemical action, thus understood, we cannot fully predict the characters of the compound from the characters of the elements. It is the speciality of chemical combination to merge nearly all the physical properties of the substances combined, and to yield a new product, where the combining elements are not recognizable. Sulphur combines with copper to form a black flaky substance, the sulphuret of copper.

There are still wanting general laws that would serve us to compute the resultant of a chemical combination; we know only that weight is not lost, and that the law of definite properties holds.

The analogy of Chemical Combination has been applied to mental and social combinations. Thus, the complex emotions of the mind are often so far different from their constituents, as scarcely to suggest these to the mental analyst. The moral sense, for example, is declared by many to be a simple faculty, on the ground of its having no resemblance to any other simple elements of the mind.

Again, in the study of national characters, we may know that certain influences concurred in the process of formation, and yet find a difficulty in tracing them.

These, however, are mere analogies. Chemical combination is an illustrative metaphor and little besides. The analogy fails in one essential circumstance, definite combinations. The disguise of the elements or components is the only point of similarity: and that would probably be better referred to the analogy of *growth*, where the constituents entering at one stage form a product, still farther combined in succesive operations, which cannot all preserve a record of themselves.

CHAPTER V.

ELIMINATION OF CAUSE AND EFFECT.—OBSERVATION AND EXPERIMENT.

1. The enquiry into causation is usually presented in nature as a complication of influences and arrangements, some concerned and some not concerned in the cause or the effect sought.

For instance, a man in good health goes to a new place and a new occupation. His health gradually fails. There must be a cause for the failure; assuming that he could have retained his health in his original abode and occupation, the cause must lie in the new circumstances that he is placed in. These new circumstances are perhaps numerous; the climate may be hotter or moister, not to mention many other variations; the man's new pursuits and recreations may be widely different from his old. Now, while some of these differences must have some share in the effect, others probably have no share; and the problem lies in disentangling the one class from the other; in separating the operative from the inoperative surroundings.

The case now supposed represents the inductive search in its extreme speciality, and as it appears in the commoner practical questions. A more general enquiry is exemplified in determining the effects of given agents, as heat, moisture, electricity, ozone, light, foods or medicines, on the human constitution. Every one of those agents has a variety of properties, or modes of action; in the case supposed, some are operative and some not; and we must discriminate the one class from the other.

Again, we may propose a still more general enquiry—What is the common antecedent to the effect denominated Heat, or the peculiar fact or situation always recurring when there is an increase in the temperature of material bodies? In looking at the incidents attending the development of heat in any instance, we find them to be numerous and various; and we have to find some mode of separating the inefficient from the efficient elements of the situation.

We know from the law of Causation, even in the less explicit form (Conservation being left out of view), that in the

changes going on in the world, the present situation is the result of the previous situation; and if that previous situation were reproduced so would the present. But this is not all; for we may be able to show that if a *certain part* of the previous situation were reproduced, the present would follow; we can put aside all otiose or inert accompaniments and reduce the antecedent circumstances to those really operative. This is the process of INDUCTIVE ELIMINATION, required alike in special and in general enquiries as to cause and effect.

Yet farther, we may find the sequence of a past and a present situation to consist in a *plurality* of distinguishable sequences, which we may analyze and isolate by the methods to be pointed out. Political causation is almost always a complication of many distinguishable threads.

2. Preparatory to the disentangling or eliminating process, we make, in our own mind, an *analysis* of the situation.

As the final end is to discriminate the necessary from the unnecessary elements of the situation, we begin by a separate enumeration of all the circumstances, taking care to reduce each to its simplest components. If a man has lost his health, in a certain locality, we first suppose to ourselves what may be the distinct agents concerned; we analyze the climate into all its constituent circumstances—temperature, moisture, fluctuations, purity of air, and so on; we analyze the peculiarities of his mode of nourishment, occupation, habits, state of mind; and the more thorough-going the analysis, the better are we prepared for the operation that is to follow. Indeed, an insufficient analysis will of itself defeat the best laid schemes of elimination. Newton's investigation of the planetary motions owed its success to his analyzing the course of each planet into a central tendency towards the sun, and a tangential tendency. This separation was the first clue to the mystery. In any enquiry into the cause of some effect due to the sun, as for example, sun-stroke, the different known constituents of the solar beam—heating, lighting, and chemical rays—should be separately viewed as the possible cause.

The ability to perform these mental analyses is partly dependent on the state of knowledge at the time. Thus, we now know, what was not known in the beginning of the last century, the constituents of the atmosphere; we are therefore prepared for an enquiry, according to the methods of elimination, into the precise cause of any atmospheric effect. If it is proposed for enquiry, why does meat putrefy in the air, we keep

in view the distinct constituents—nitrogen, oxygen, water, carbonic acid, dust, living germs; as among these, or among some concurrent action of these the cause must be found. So, it is only of late, that the analysis of the solar ray has indicated the so-called chemical rays in addition to the luminous and the heat-giving rays.

It may be farther remarked, that this analytic ability is a special mental aptitude personal to the enquirer, and indicating the scientific faculty.

3. In separating the essential from the non-essential accompaniments in cause and effect, the course is to *vary the circumstances,* for which end we must resort to Observation and Experiment.

The different antecedents and consequents being separated in thought, we have to ascertain which antecedent is connected with a given consequent. Having usually a plurality of antecedents, or a plurality of consequents, or both, we need to single out the connected couples of antecedent and consequent. This requires us to look for other instances where the groupings are different, and to note what happens when particular antecedents or consequents are wanting: an operation described by Bacon as 'varying the circumstances.'

The varied circumstances, or groupings, are so many new facts attainable only by Observation, to which we may add Experiment. The distinction between these two processes is not fundamental, and is seldom important. Observation is *finding* a fact, Experiment is *making* one. The worth of the fact depends on what it is in itself, and not on the manner of obtaining it. Both methods are used as far as possible.

The advantages of Experiment are not confined to the obvious circumstance of multiplying the facts, important as it must often be to multiply them. A second consideration is the power that we may have of suiting the facts to the case in hand—of producing *the sort of variation* that we need. Thus, in order to ascertain which of the gases of the atmosphere supports combustion, or animal life, and what are the elements that bring about putrescence and decay, we must, by means of experiments, separate artificially one or another of the gases from the rest; such separation not being provided for us in nature.

Dr. Balfour Stewart remarks, with reference to an investigation by Dulong and Petit as to the cooling of a body surrounded by a gas, that the research was a very troublesome one, from

the variations that had to be made in the temperature of the body, and in the density, temperature, and chemical nature of the gas.

A third superiority of Experiment over Observation lies in the power of producing a phenomenon *under known circumstances and surroundings*, so as to take account of all extraneous influences. Thus, instead of observing electricity in thunder discharges, we evolve it in a room where we know all the modifying influences. For the examination of magnetism, a house is constructed wholly of wood, so that the local disturbance of pieces of iron may be prevented. Likewise, the best opportunity for the study of disease is in hospitals, where the sick are wholly under the control of the physician.

Experiment finds its greatest scope in Physics and in Chemistry. It is admissible in Physiology, in the Human Mind, and in Human Society, with limitations easily divinable by any reflecting student.

In the situation of enquiring into the Cause of a given Effect, Experiment is for a moment unavailing. We can try the effect of a given cause, but we cannot try the cause of a given effect. Assuming heat as an agent, we can make experiments on its various powers or capabilities; but given the heat of a fermenting mass, as an effect, we cannot, by experiment, get out the cause. We must first *conjecture* a cause; experiments may then be instituted to find out the effects of that supposed cause; if these tally with the effect in question, we have made out our point.

The problem of Causation may thus be presented in both aspects—given a cause to find the effect, given an effect to find the cause—but the experimental solution is one; namely, to watch the effect of an assumed cause. The course of the phenomenon flows in one way; cause first, effect second. When we seem to be working backward, we are in reality working forward.

REVIEW OF THE COMPLICATIONS OF CAUSE AND EFFECT.

4. The Inductive Elimination of Causes and Effects may be illustrated by a review of the various complications actually met with.

We have already adduced examples of the complications that have to be unravelled, in order to assign the neat effects of a cause, or the causes of an effect. We are able to present a more comprehensive view of the actually occurring entanglements.

Those natural aggregates, termed Kinds by pre-eminence, are marked by the concurrence, in a single object, of many different properties. Oxygen, carbon, phosphorus, iron, mercury, platinum—have each a great number of distinct powers or activities; hence, when the introduction of any one of them is followed by some change in the things they are brought into contact with, we are at first uncertain which of all the many properties of the substance is the operative circumstance. Carbon, for example, is found to absorb gases in large amount; which suggests the enquiry, which of the properties of carbon is this owing to:—its specific gravity, porosity, blackness, amorphous structure, or any other? Again, mercury has certain medicinal effects; and we desire to know which of its many properties is the causative circumstance. Platinum, in a finely divided or spongy state, brought into contact with a stream of hydrogen, makes it ignite. What does this depend upon?

So then, in the elementary bodies of Chemistry, the simplest substances known to us, there is a great concourse of antecedents present whenever any one is brought into play. But, in nature, these are usually found mixed together (I am not alluding to Chemical combination, which yields new substances) in great varieties of compounds. Thus, the Atmosphere is a mixture of two simple bodies—nitrogen and oxygen; various known chemical compounds—water, carbonic acid, and ammonia; and a great many other gaseous effluvia, together with solid particles, partly dust and partly ova of plants and animals. Moreover, it possesses at each moment a certain temperature, a certain electrical condition, and perhaps other peculiarities. Thus, when the atmospheric air is presented to us as a cause or agency, the possible variety of antecedents is very great. Many researches have been occupied in eliminating the causal conditions in combustion, in vegetable and in animal life, in putrefaction, in spontaneous generation (so-called), &c.

Again, the sea is not pure water, but a solution of numerous saline bodies.

Most minerals are mixed substances. A geological stratum is highly compound; and when certain vegetables are found to grow in a particular soil, elimination must be applied to ascertain which are the needful constituents.

In Vegetable and in Animal Kinds, the complication is still greater. The chemical constituents of plants and of animals have very complex atoms, whose disintegration may yield

a variety of different products. Hence, vegetable and animal substances used as food, as medicines, as dyes, &c., have many possible modes of operating. We must, however, when living bodies are agents, farther take into account the organic or living structure; the poison of a living plant or animal has powers of derangement quite different from the chemical action of its chemical constituents.

The complication in the world of Mind is very great. A human being is by nature many-sided, and by education still more so. Hence, when one person exercises an influence upon another, it is far from obvious, at first sight, by what peculiarities the effect arises. So again, in the explanation of motives, a historian is often baffled to select the one that actually swayed a given effect.

The operations of Government are ramified in their consequences. A single enactment—the imposition of a tax on windows or its removal, free-trade, or its opposite—operates variously according to circumstances.

WEAPONS OF ELIMINATION.

5. It is in the comprehensive Law of Causation itself, once established by Induction, that we have the instruments for eliminating causes and effects in the detail.

As already said, there is but one proper Inductive Method —Universal Agreement; there is, in the first instance, no shorter cut to an Inductive Generalization. We must go through the labour of a full examination of instances, until we feel assured that our search is complete, that if contrary cases existed, they must have been met with.

By such thorough-going examination, various inductive laws have been established, including that momentous truth called the Law of Causation. Now, in whichever of its two properly scientific aspects, we view this law—whether in the less suggestive but perfectly accurate form of Uniformity of Sequence, or in the new and better form of Conservation accompanied with Collocation, we find in it a means of shortening the labour of ascertaining specific causes and effects. By applying the general law, in either form, there is often a possibility of proving causation by a single instance.

Thus, to take the first form of Causation—'Every event is uniformly followed by some other event; and every event is uniformly preceded by one or other of a definite number of events':—given an antecedent, one consequent succeeds; given

a consequent, some one of a few definite antecedents has preceded. Now from this it follows, that whenever an agent is introduced into a quiescent state of things, and when certain changes follow at once on that fact, the sequence happening once will happen always. Nothing springs out of nothing. Nature in the matter of sequences is uniform; and a single case, cleared of ambiguities, establishes a law. By the stroke of an axe, a block is cleft; the same effect will always follow the same cause. Hence, a single experiment in the laboratory may establish for ever a casual property.

On the second or more precise form of Causation, there is a definite transfer of motive power under some given arrangement of things. We know, by this law, without any new observation, that a blow with a hammer will realize its equivalent, either in mechanical energy, or in some form of molecular force. If in a certain situation, it splinters a stone, it will always do the same thing, in the same situation. In a different arrangement, it raises the temperature of a surface; and what it does once, it does always. All that we have to settle empirically in this form of the law, is the transfer attending each collocation, and the collocation attending each transfer. By induction proper (universal agreement) we have already ascertained this to be uniform, and accordingly pronounce upon a single clear instance.

There is thus only one Inductive Method at the foundation (Agreement), but there are several *Deductive* Methods, or methods depending upon the grand generalization of Cause. For instance, the method known as the 'Method of Difference,' is not an inductive but a deductive method; for, without the law of Causation, the method would be incompetent. Even the 'Method of Agreement' as employed for the purpose of elimination, supposes the Law of Causation, and is to that extent a deductive method.

6. The Law of Causation involves the three following affirmations, each of which is the groundwork of a process of Elimination.

(1) Whatever antecedent *can be left out*, without prejudice to the effect, can be no part of the cause.

A cause is what produces an effect. As the presence of the cause is the presence of the effect, so the absence of the cause is the absence of the effect. The absence of the cause, with the presence of the effect, would be a contradiction of the law. We are sure, therefore, that whatever can be omitted

or withdrawn without making any difference to the effect in question, is not the cause, or any part of the cause. If we cut a string that we suppose to be the support of a weight, and the weight continues to be supported, the string is not the support.

Upon the Law of Causation, viewed on this side, reposes Mr. Mill's Method of elimination by *Agreement*. A certain effect remains after the successive withdrawal of all the antecedents except one; which leaves that one in sole and undisputed possession, and therefore *the* cause.

(2) When an antecedent *cannot be left out* without the consequent disappearing, such antecedent must be the cause or a part of the cause.

This affirmation, likewise, is implied in the law. It presents the other side of the same linking of cause and effect; absence of the cause is absence of the effect. Whatever, by disappearing, makes the effect to disappear, is by that very fact an essential or causal condition. If the cutting of a string *is* the falling of a weight; the string is the support of the weight.

This aspect of cause gives the decisive Method of *Difference;* the method whereby a single instance may be incontrovertible proof of a cause.

(3) An antecedent and a consequent rising and falling together *in numerical concomitance* are to be held as Cause and Effect.

This is Causation in the more special aspect of Conservation, and is directly implicated in that principle. In the transfer of moving power, the quantity gained is the quantity lost; and the tracing of quantitative concomitance is our very best clue to the force operative in a given effect. As the combustion of a locomotive is increased, so is the steam power.

In those agencies that merely bring about a collocation, there is no numerical ratio between the agent and the result. A slight touch is enough to complete the electric circuit, and a double vehemence adds nothing to the energy of the circuit.

The process now described is the Method of *Concomitant Variations*.

These are the three chief methods of Eliminating the unconcerned circumstances present in cause and effect. After considerable progress has been made in the discovery of causes, recourse may be had to a farther proceeding, namely, to allow for the influence of all known causes, and to attribute

what remains of the effect to what remains of the cause. This also is a proper inference from the Law of Causation. It is termed the Method of *Residues*.

The Method of Agreement may be employed *negatively*; that is, cases may be found where cause and effect are uniformly *absent together*. We may call it *Agreement in Absence.* When this circumstance can be conjoined with the positive method—Agreement in presence—an approach is made to the decisive cogency of the Method of Difference. Mr. Mill has given to this conjoint mode the designation—*Joint-Method.*

The following chapter will exemplify the employment of these Five Methods of Inductive (or Deductive) Elimination in investigating Cause and Effect.

It is not possible to separate from the thorough working of these instruments of Elimination the process of *generalizing*, or attaining to Inductive generalities. In carrying out the Method of Agreement, for example, the collation of a large number of instances where a cause or an effect is present, cannot fail to suggest laws of causation of a higher generality than the enquirer sets out with. Nevertheless, it will not be expedient to dwell upon this generalizing operation while we are bent upon the eliminating process. Generalization belongs to *Discovery*; Elimination is *Proof;* and Proof, more than Discovery, is the end of Logic. Still, we shall have to make room for a consideration of the best modes of arriving at the higher generalities.

CHAPTER VI.

THE EXPERIMENTAL METHODS.

1. There are three chief methods of eliminating the cause of a phenomenon from the neutral or indifferent accompaniments—Agreement, Difference, and Concomitant Variations.

METHOD OF AGREEMENT.

2. The Method of Agreement is expressed thus:—If two or more instances of a phenomenon under investiga-

tion have only one circumstance in common, that circumstance is the cause (or effect) of the phenomenon.

The instances are studiously varied so as to leave out in turn all the circumstances attending the phenomenon. Whatever is left out, in any one instance, without detriment to the effect, cannot be the cause; the possibilities are gradually reduced in number; and, if the means of elimination are complete, the enquiry terminates in assigning one circumstance that has never been wanting where the phenomenon appears.

The method is illustrated symbolically thus:—Let A represent a cause and *a* an effect In nature we seldom have A followed by *a* alone; were such isolation the rule, the Experimental Methods would be unnecessary. What we find is A in combination with other things as A B C, and *a* also in combination, as in *a b c*. But, now, if these conjunctions were rigid and invariable, we should have no opening for the methods. The real fact is, however, that though a cause may be always in combination with other agents, it is not always in the *same* combination; at one time the union is A B C, at another time A B D, and again A C E; there being corresponding conjunctions in the effects—*a b c*, *a b d*, *a c e*.

If we suppose, then, the instances—

A B C giving *a b c*,
A B D giving *a b d*,
A C E giving *a c e*,

we reason thus. So far as the first instance is concerned—A B C giving *a b c*, the effect *a* may be produced by A, or by B, or by C. In the second instance—A B D giving *a b d*, the cause C is absent, the effect *a* still remaining; hence C is not a cause of *a*. In the third instance—A C E giving *a c e*, —B is absent, *a* remaining; hence B is not a cause of *a*. The only antecedent persisting through all the instances is A; when *a* is present as a consequent, A is always present as an antecedent. If, then, we are sure that every other antecedent circumstance has been removed in turn, the consequent *a* still surviving, we have conclusive evidence that A is a cause, condition, or invariable accompaniment of *a*.

It matters not which is the form of the enquiry,—given an effect to find a cause, or given a cause to find an effect. The first is supposed to be the more frequent occurrence. Science, from of old, was

—— rerum cognoscere *causas*.

If the problem be given in the first form, the proof is always given in the second; we try a cause to see what effect

will follow, which proves at once that the consequent is the effect of the antecedent, and that the antecedent is the cause of the consequent; the two affirmations being identical.

Although our professed object now is to unfold the Inductive elimination of Cause and Effect, having already disposed of the case of Co-existence as Co-inhering Attributes, yet, in expounding the Methods, we must receive instances indiscriminately, as we do not at first know how they will turn out. There are many connexions of Cause and Effect that appear as Co-existences, and there are instances that we must leave undecided, being unable to assign the ultimate nature of the union. The more obvious tests of Causation are these:—(1) sequence in time, as when innoculation is followed by the small-pox-pustule; (2) expenditure of energy, as when a cannon ball shatters a fort. Where these tests are wanting, as in co-inhering powers of the same substance—for example, gravity and inertia—we are left to presume co-existence, there being, as alternative possibilities, mutual implication, and the co-existing effects of a common cause.

This explanation is more especially called for in commencing the Method of Agreement—the universal or fundamental mode of proof for all connexions whatever. Under this method in particular, we must be ready to admit all kinds of conjunctions; reducing them under Causation, when we are able, and indicating pure Co-existence when the presumption inclines to that mode.

As a simple example, we may take the case of *the conversion of solid bodies into liquids*, and the farther conversion of liquids into gases. The bodies so converted are of every possible variety of properties; the one circumstance common to all the instances of such conversion is the application of heat. The elimination is complete as regards this antecedent, which is therefore correctly assigned as the essential condition or cause. We may apply in this example, the most decided test of Causation, the expenditure of energy or force; we should never regard the fact as a mere Co-existence.

The next example is of a different character.

The peculiar phenomenon known as the interference of polarized light—consisting in the exhibition of rings of alternating or 'periodical' colours, when a polarized beam of light passes through certain transparent substances—may be propounded for investigation. We may ask—is there any other property or phenomenon always present in the bodies that show this peculiar effect? Now, the bodies must, as a

matter of course, be transparent; but all transparent bodies do not exhibit the polarized bands; hence, transparency is eliminated. By farther comparison of instances, we find that there is no constant mode of colour, of weight, of hardness, of form (crystalline), of composition (physical or chemical); so that no one of all these properties is concerned in the phenomenon. There is, however, one property common to all the substances that furnish these coloured bands, they are all *doubly refracting* substances, that is, present two images of things seen through them obliquely. By Agreement through all known substances, there is proof of the concurrence of these two properties.

It is not ascertained, however, and cannot be ascertained by Agreement alone, whether the two facts are cause and effect, or whether they are a case of co-existence without causation. Agreement is the method of proof for all conjunctions whatsoever—whether Causation or Co-existence. The enquiry belongs to a particular class—the conjoined Properties of Kinds, where there *may* be laws of co-existence without causation. The decisive criteria of causation are wanting in the case.

To take a third example. In flowers, there is a remarkable concurrence between the *scarlet colour* and the *absence of fragrance*. The following quotation gives a selection of instances.

'Among all the colours that blooms assume, none are less associated with fragrance than scarlet. We cannot at present recollect a bright scarlet blossom that is sweet-scented—yet no other colour among flowers is more admired and sought after. Scarlet prevails among Balsamina, Euphorbia, Pelargonium, Poppy, Salvia, Bouvardia, and Verbena, yet none of the scarlets are of sweet perfumes. Some of the light-coloured Balsams and Verbenas are sweet-scented, but none of the scarlets are. The common Sage, with blue blooms, is odoriferous both in flower and foliage; but the scarlet Salvias are devoid of smell. None of the sweet-scented-leaved Pelargoniums have scarlet blooms, and none of the scarlet bloomers have sweet scent of leaves nor of blooms. Some of the white-margined Poppies have pleasant odours; but the British scarlets are not sweet-scented. The British white-blooming Hawthorn is of the most delightful fragrance; the scarlet-flowering has no smell. Some of the Honeysuckles are sweetly perfumed, but the Scarlet Trumpet is scentless' (ELDER, American Gardener's Monthly).

Fourth Example. The *North-East wind* is known to be specially *injurious* to a great many persons. Let the enquiry be—what circumstance or quality is this owing to? By a mental analysis, we can distinguish various qualities in winds; —the degree of violence, the temperature, the humidity or dryness, the electricity, and the ozone. We then refer to the actual instances to see if some one mode of any of these qualities uniformly accompanies this particular wind. Now we find, that as regards *violence*, easterly winds are generally feeble and steady, but on particular occasions, they are stormy; hence, we cannot attribute their noxiousness to the intensity of the current. Again, while often *cold*, they are sometimes comparatively warm; and although they are more disagreeable when cold, yet they do not lose their character by being raised in temperature; so that the bad feature is not coldness. Neither is there one uniform degree of *moisture*, they are sometimes wet and sometimes dry. Again, as to *electricity*, there is no constant electric charge connected with them, either positive or negative, feeble or intense; the electric tension of the atmosphere generally rises as the temperature falls. Farther, as respects *ozone*, they have undoubtedly less of this element than the South-West winds; yet an easterly wind at the sea shore has more ozone than a westerly wind in the heart of a town. It would thus appear that the depressing effect cannot be assigned to any one of these five circumstances. When, however, we investigate closely the conditions of the north easterly current, we find that it blows from the pole towards the equator, and is for several thousand miles *close upon the surface of the ground;* whereas the south-west wind coming from the equator descends upon us from a height. Now, in the course of this long contact with the ground, a great number of impure elements—gaseous effluvia, fine dust, microscopic germs—may be caught up and may remain suspended in the lower stratum breathed by us. On this point alone, so far as we can at present discover, the agreement is constant and uniform.

What is the conclusion? As Agreement by itself does not decide that conjoined circumstances are cause and effect, we must find some mode of excluding Co-existence, and rendering the case one of succession. When the two circumstances are plainly in succession, as when a fracture follows a blow, uniform agreement (with elimination) proves causation; when they are not demonstrably successive, the agreement fails in this respect.

Now, there is a general belief that the two events supposed—the east wind and the uncomfortable sensations—are not contemporaneous, but in succession; the wind first, the feelings afterwards. This belief is supported by the circumstance that a change of feelings, must have, according to the law of causation, an antecedent condition; and if all antecedents, besides the one above named, are eliminated, that one is the cause, or an essential part of the cause.

The phenomenon to be explained is not a permanent fact or potentiality, like polarization or double refraction, it is a temporary manifestation, and requires some causal circumstance to bring it forth. In this respect, it resembles the *actual display* of one of these optical properties; it cannot happen without a suitable agent and collocation, which is properly a cause of the appearance.

If then, the elimination be supposed complete, there is a proof by Agreement that the deleterious influence of the east wind is due to the circumstance named; and the case exemplifies the eliminating efficacy of the method.

In the foregoing example, we cannot withhold from our mind a certain *presumption* in favour of the result, grounded on our knowledge of the deleterious tendency of atmosphere impurities caught up from the surface of the ground. This is a circumstance not properly belonging to the proof by Agreement; it is a confirmation from *deductive* sources. The addition of such a presumption always operates strongly on our belief; the total absence of it leaves a considerable shade of uncertainty in all the methods, but most of all in Agreement. The third example shows this deficiency; we are not at present aware of any connexion of a causal kind between the scarlet colour of flowers and the absence of fragrant odour; the proof of the law rests upon the Agreement alone. That method of proof is final, only when the elimination has been exhausted, by variation of circumstances, and when the coincidence has been shown through all nature, so as to establish a law of Universal Co-existence.

Fifth Example. Let the phenomenon given be *Crystallization*, and let the thing sought be the antecedent circumstances, positive and negative, of the formation of crystals. This is a case of succession, and therefore of Causation.

We must begin by collecting instances of the effect. In the following series, the circumstances are purposely varied with a view to elimination:—

1. Freezing of water.

2. Cooling and solidifying of molten metals and minerals.
3. Deposition of salts from solutions.
4. Volatilizing of solutions.
5. Deposition of solids from the gaseous state, as iodine.
6. Pressure.
7. Slow internal change, as in rocks.
8. The transformation of metals from the tough to the brittle condition, by hammering, vibration, and repeated heatings and coolings.

Looking at the first and second instances—ice, and the solidifying of molten metal—we discover two antecedent circumstances, namely, lowering of temperature, and change from the liquid to the solid state.

The third instance—deposition of salts from solution—agrees in the same two circumstances, there is a lowering of temperature, and also a change from liquid to solid.

The fourth instance—the volatilizing of solutions, as in boiling down sea-water—appears to fail in the matter of cooling, but still contains the circumstance of prior liquidity; the prominent fact is that the solvent is driven off, and the dissolved substance thereby compelled to resume the solid state.

The fifth instance—the deposition of solids at once from the gaseous state, as in the case of iodine—seems to eliminate prior liquidity. We must then shift the ground, and, for liquidity, substitute one of the two higher states of matter.

The sixth instance is 'heavy and long continued pressure upon an amorphous substance;' principally shown in geology. This would eliminate the prior liquid or gaseous condition, and bring to view the forced approximation of the constituent particles of bodies. But the same circumstance accompanies all the previous cases, being merely a different expression of what is common to them. We know heat as forcibly enlarging the bulk of bodies—making their particles mutually repellent; the withdrawal of this force leaves the attractions of the particles free to operate.

The seventh instance—slow geological transformation—unless viewed by the light of the circumstance just named, is difficult to interpret. It is not, however, incompatible with the predominance of the molecular attractive forces by the abatement of the repellent forces.

The eighth instance—change of metals from the tough to the brittle state—is a true case of crystallization; brittleness is accompanied with an imperfect crystalline arrangement. The effect is produced by cooling after hammering; by re-

peated heating and cooling; by long-continued vibration or concussion:—all which influences tend to expel the structural heat of the substance; the consequence being that the molecular attraction is more preponderant.

We have thus eliminated Cooling, Deposition from Solution, and Prior Liquidity; and have found but one uniform antecedent—the increased scope and operation of the molecular or solid-forming cohesion; to which point, however, these other circumstances really tend; they are all of them remoter antecedents of the one constant antecedent. The examination of the instances has enabled us to *generalize* the phenomenon, as well as to establish the generality upon evidence, namely, the evidence of Agreement.

As we have stated this enquiry, it is a clear case of Cause and Effect. We have sought the antecedent circumstances whereby a body in an amorphous or uncrystallized state becomes crystallized; and we find that there is an expenditure and re-distribution of power or energy. The result of the expenditure is not an active manifestation, as when we produced mechanical force, or heat; it is an arrangement, or structural collocation; a case already contemplated (p. 35) among the results of expended force.

Sixth Example. Let us next apply the method to eliminate the cause, or the antecedent conditions essential to the production and maintenance, of *Light*.

Now, the most constant circumstance is a *high temperature*; solid bodies become luminous at a temperature of from 980° to 1000° Fahrenheit. So far, there is a remarkable unanimity. It is found, however, that gases do not always become luminous at this temperature, nor at a much higher; a current of gas may be raised to upwards of 2000° F. without being luminous; whence we conclude that the *state* of the body is also a condition. Again, the *electric spark* is a luminous effect, which would give the disturbance of the electric discharge as an antecedent. As there is a possibility, however, that the great violence of the discharge may be accompanied with sudden rise of temperature, this may be merely another form of heat. We should need to show, by varying the instances, that high temperature is not essential to the spark. In the next place, certain substances give light at common temperatures, to which fact has been given the name *phosphorescence*. Some minerals, gently heated, emit a feeble light, which soon ceases, and cannot be renewed until the body has been exposed to the sun or the electric spark. This is still a

form of heat, but not of the intense degree of ordinary light. More peculiar still is animal phosphorescence, as the glow-worm, fire-fly, and certain sea animalcules. Here the accompaniment is a special mode of vitality hitherto uneliminated, and excluding the circumstance of high temperature (Mr. Herbert Spencer suggests that it is an incident attending oxidation). Once more, a faint flash of light occurs with certain substances in *the act of crystallizing*.

We may thus collect from Agreement, that ignited solids at the temperature of 1000° are luminous, and that an electric discharge is luminous; but we cannot at present lay down any wider generalization. Excepting the very general fact of molecular disturbance of some kind or other, which we are unable to qualify in the precise mode concerned in the effect, our comparison of instances does not point to a constant circumstance. For the present, we regard Light as having a plurality of causes.

As farther instances of Agreement, we may quote the proof of the coincidence of Sleep with low nervous action, which means a feeble cerebral circulation; also, the connexion of Memory with the intensity of Present Consciousness. The uniformity of these conjunctions under all varieties of other conditions is the evidence afforded by Agreement. The Relativity of Knowledge is established partly by Agreement, partly by the method of Concomitant Variations, as will be shown.

The cogency of Agreement is manifestly in proportion to the thoroughness of the elimination. Whatever circumstance has never been eliminated is a possible cause. There are not a few instances, as in the action of drugs, where nature does not provide the variety requisite for a thorough elimination. The complicacy of the Natural Kinds passes our means of extrication by Agreement alone.

METHOD OF DIFFERENCE.

3. Elimination by Difference is expressed in the following canon :—If an instance where a phenomenon occurs, and an instance where it does not occur, have every circumstance in common except one, that one occurring only in the first ; the circumstance present in the first and absent in the second, is the cause, or a part of the cause, of the given phenomenon.

We are supposed to have two instances and only two. Each is a complex sequence, a group of antecedents followed by a

group of consequents. The two complex sequences differ by only a single sequence, present in the one, and absent in the other. Thus the sequence A B C D gives *a b c d*, and B C D gives *b c d*: the only difference being the presence of A in the antecedent, and of *a* in the consequent, of one sequence, and the absence of these in the other sequence. Supposing A B C D changed into B C D, by the loss of A; while at the moment *a b c d* is changed into *b c d* by the loss of *a*; we have a proof of the connexion of A with *a*. Indeed, the assertions are identical; to say that the disappearance of one thing is followed by the disappearance of another thing, there being no other change, is merely a way of expressing causal connexion.

Difference plays a great part in our everyday inferences. The usual form is the sudden introduction of some limited and definite agency or change, followed by an equally definite consequence. When the drinking of water is followed at once by the cessation of thirst, we do not hesitate to pronounce the one fact the cause of the other. The human system is a great complication, but the only difference made upon it in two successive minutes is the sequence of drinking and the satisfying of thirst; there has been, we presume, no time for any other change to manifest itself. So when we waken a sleeper by a noise, or strike a light by the friction of a match, we infer causation; the new agency being instantaneously followed by the new effect.

The first example given, under Agreement, is also proved by Difference. That Heat is the cause of the melting of ice, of wax, or of lead, is proved by making, upon these substances, the one change of raising the temperature. Being quite sure that in the conversion of ice into water, no change has been made except this, we have a conclusive experiment of Difference to show that heat is the cause.

The same substance in two states, as solid and liquid, or as amorphous and crystallized, enables us to ascertain what effects are due to change of state. Thus charcoal, uncrystallized, is black, opaque, and a conductor of electricity; as crystallized, in the Diamond, it is transparent and a non-conductor.

A large part of our knowledge of nature and of living beings is gained by making experimental changes and watching the consequences. Our proof is the immediate result. An immediate response is satisfactory evidence in almost any department. Thus, in medicine, there is little doubt as to the operative force of purgatives, emetics, sudorifics, diuretics, narcotics, stimulants, irritants; the uncertainty attaches to

alteratives, tonics, and the protracted treatment of chronic cases. The effect of quinine, in ague, is established beyond dispute.

Whether it be to add, or to withdraw, a definite agent, a change instantly following is proved to be an effect. Even in politics, we may have a proof from difference; as in the accession or resignation of a minister, like Chatham. No other circumstances arising in the ordinary course of a year would make that total change in the course of politics that followed on Chatham's becoming minister. It could not be denied that he was the cause (in the *practical* sense of cause) of our successes in America, and on the continent of Europe. The consequences of his retirement were equally decided as proving, on the method of Difference, the vast superiority of his powers as an administrator.

Wherever Difference can be resorted to, the knowledge of causes is gained at once. In ordinary cases, the method is so obvious in its application, so satisfactory and conclusive, as scarcely to need a master to explain or enforce it. The special discipline of Logic, so far as this method is concerned, lies in showing the precautions requisite in the more complicated cases.

In Physiology, the functions of the nerves were ascertained by the experiment of dividing each in turn, and watching the effect. Whatever function is immediately arrested on the division of a nerve, is shown to be due to that nerve, or to require that nerve in order to its performance. Such experiments, however, do not exhibit the entire circle of conditions involved in the function in question. We know that the integrity of the spinal cord is necessary to sensation and to movement in the trunk and in the extremities of the body; we do not exhaustively know what else is necessary. For this more extensive knowledge we should have to multiply experiments all through the brain. If the destruction of any part interferes with these functions, that part enters into the causal conditions; if otherwise, it does not enter into those conditions.

The extension of this class of experiments to the brain exemplifies one situation where the method of Difference may be indecisive. Deep incisions in the brain, intended to affect one single organ, as the cerebellum, may injure adjoining organs; and may therefore be inconclusive as to the functions of the special organ in view. It is on this ground that Brown-Séquard objects to the views of Flourens's regarding the

function of the cerebellum. The one certain inference in such cases is, that whatever function survives, in its integrity, the destruction of an organ, cannot be exclusively due to that organ. The obverse inference is certain only on the supposition that the injury has been confined to the part affected.

With reference to the connexion of scarlet bloom with absence of odour, we have a seeming case of Difference in comparing such varieties as the white-flowering and the red-flowering hawthorn: the one fragrant, the other not. In the complicacy of Kinds, we can seldom be sure that a variation is rigidly confined to the circumstances that are apparent. Moreover, where there is not a clear case of Causation, Difference is insufficient to prove a coincidence.

Sir G. C. Lewis lays it down as essential to the validity of a proof by Difference, that we should know, by a previous induction, the *general adequacy* of the assigned cause to the production of the effect. When we infer that a man, shot through the heart, drops down dead, we need to know, he thinks, that, as a general rule, a gunshot wound in the heart, is a cause of death. To this remark the reply is, that practically we do make use of such previous knowledge, but it is not essential to the method of Difference. Provided we are quite sure that the new agent is the only change that has preceded the effect, the instance is conclusive, *on the Law of Causation solely*. The use of a more specific induction is to supply the defect of certainty in the instance itself. There may be other unseen agencies at work, as well as the one supposed, and this is the only ground either for invoking a general presumption, or for multiplying instances of the phenomenon. In practice, we seek both for presumptions (from prior inductions) and for repetition of instances; but an ideally perfect instance of Difference, in a case of Causation, is conclusive in itself.

Agreement and Difference can be easily compared as to their respective advantages and disadvantages. Agreement needs a large number of instances, but their character is not restricted. Any instance that omits a single antecedent contributes to the result; the repetition of the same instance is of use only as giving means of selection. Difference requires only one instance; but that one is peculiar, and rarely to be found.

A great extension is given to the power of Agreement, by extending it to *agreement in absence*. When such cases are

conjoined with those where the agreement is in *presence*, there is an approach to the conclusiveness of the method of Difference. This double employment of the method of Agreement is brought forward by Mr. Mill under the designations—the 'Joint Method of Agreement and Difference,' and the 'Indirect Method of Difference.' It might also be called the 'Method of Double Agreement.'

JOINT METHOD.

4. The canon of this Method is:—If two or more instances where the phenomenon occurs have only one circumstance in common, while two or more instances where it does not occur have nothing in common save the absence of that one circumstance; the circumstance wherein alone the two sets of instances differ, is the effect, or the cause, or a necessary part of the cause of the phenomenon.

If we require to ascertain, under this method, that A is the cause of *a*, or *a* the effect of A, we add, to the instances of uniform presence of A and *a*, other instances of uniform absence, as B F G followed by *b f g*, C H I followed by *c h i*, and so on. If we have never discovered A wanting as an antecedent without having *a* absent as a consequent, there is a strong additional presumption that A and *a* are united as cause and effect—a presumption that may approach to the certainty of the method of Difference.

It is a confirmation of the cause, suggested by Agreement, of the noxiousness of the North-East wind, that the South-West wind, the genial and wholesome current, is wanting in the circumstance assigned. It descends upon us from the elevated regions of the atmosphere, where impurities are highly diluted by dissemination.

Again, to revert to the example of Crystallization. Let us review the non-crystallized solids, and note the mode of their formation. The amorphous stones and rocks, as sandstone, chalk, &c., are known to be sedimentary deposits from water. Before being solidified, they existed as solid particles; they were not dissolved in water, neither did they exist in a molten condition. This Agreement in absence would confirm the inference from Agreement in presence—that (so far as certain instances went) crystals existed in a previous higher condition. But the general inference, from the full comparison of examples, was the superior play given to the molecular attraction by counterworking the molecular repulsion. Now,

this general fact is absent from all mere sedimentary deposits; these bodies have no aid, in the shape of loss of heat or other cause, to their molecular attractions.

The comparison of the amorphous rocks yields another circumstance, namely, *the irregular mixture of different substances*. For, although in a mud sediment silica or alumina may prevail, neither is ever pure; and the mixture of different elements is a bar to crystallization, unless they are of the kind called isomeric (from crystallizing alike). There is more to be got over in crystallizing compounds of unlike elements, and the crystals must be deficient in regularity.

Another uncrystallized class comprizes the vegetable and animal tissues. In their case, however, the antecedent circumstances are too complicated and obscure to furnish insight; they rather stand in want of illustration by the parallel lights of more obvious cases. Besides, there is in them a method and order of aggregation more analogous to the crystallized, than to the amorphous solids.

A third class includes the Colloids, or glue-bodies, of Graham (represented by gum, starch, gelatin, albumen, tannin, caramel). They are not confined to the viscid form of glue, but include compact solids, as flint. The points of contrast between these and crystallized bodies are numerous and important. Their mode of formation is various; many of them are the products of living bodies, and therefore share in the complication of living growth. Flint is an aggregate of particles of silica, which particles were originally the shells of animals, and therefore also organic in their formation. In this case, the molecular attraction of silica, in its progress towards crystallization, is thwarted by the pre-existing forms of the silicious particles.

It would require too long a discussion to show the bearing of the colloid peculiarities on the question as to the antecedents of the crystalline formation. Enough has been given to show the working of the method of Obverse Agreement.

METHOD OF CONCOMITANT VARIATIONS.

5. Canon of the Method:—Whatever phenomenon varies in any manner whenever another phenomenon varies in some particular manner, is either a cause or an effect of that phenomenon, or is connected with it through some bond of concomitance.

The effects of Heat are known only through proportionate

variation. We cannot deprive a body of all its heat; the nature of the agency forbids us. But, by making changes in the amount, we ascertain concomitant changes in the accompanying circumstances, and so can establish cause and effect. It is thus that we arrive at the law of the expansion of bodies by heat. In the same way, we prove the equivalence of Heat and Mechanical Force as a branch of the great law of Conservation or Persistence of Force.

The proof of the First Law of Motion, as given by Newton, assumed the form of Concomitant Variations. On the earth, there is no instance of motion persisting indefinitely. In proportion, however, as the known obstructions to motion—friction and resistance of the air—are abated, the motion of a body is prolonged. A wheel spinning in an exhausted receiver upon a smooth axle runs a very long time. In Borda's experiment with the pendulum, the swing was prolonged to more than thirty hours, by diminishing friction and exhausting the air. Now, comparing the whole series of cases, from speedy exhaustion of movement to prolonged continuance, we find that there is a strict concomitance between the degree of obstruction and the arrest; we hence infer that if obstruction were entirely absent, motion would be perpetual.

The celebrated experiment of carrying the barometer to the top of Puy de Dôme was a proof by variation of the connexion between the pressure of the air and the rise of the mercury.

By Concomitant Variations, we derive one of the proofs of the connexion between the brain and the mind. In the same manner, we learn to associate health with the healthy agencies, and diseases with noxious agencies.

The doctrine that change of impression is an essential condition of consciousness, from which proceeds the theory of Relativity as applied to feeling and to knowledge, is most strikingly attested by Concomitant Variations. The intensity of a mental impression notably varies according to the greatness of the transition from one state to another: witness the influence of novelty, of all great changes of circumstances, of suddenness and surprise.

The Statistics of Crime, reveal causes by the method of Variations. When we find crimes diminishing according as labour is abundant, according as habits of sobriety have increased, according to the multiplication of the means of detection, or according to the system of punishments, we may presume a causal connexion, in circumstances not admitting of the method of Difference.

The Concomitance may be *inverse*. Thus we find that the tendency to chemical action between two substances increases as their cohesion is diminished, being much greater between liquids than between solids. So, the greater the elevation of the land, the less the temperature, and the more scanty the vegetation.

Parallel Variation is sometimes interrupted by critical points, as in the expansion of bodies by heat, which suffers a reverse near the point of freezing. Again, the energy of a solution does not always follow the strength; very dilute solutions occasionally exercise a specific power, not possessed in any degree by stronger. So, in the animal body, food and stimulants operate proportionally up to a certain point, at which their farther operation is checked by the peculiarities in the structure of the living organs.

The properties of highly rarefied gases do not exhibit an exact continuity of the phenomena that vary with density. In a perfect vacuum, there is no electrical discharge; but the variations of the discharge, in highly rarefied air, do not proceed in exact accordance with the degree of rarefaction.

We cannot always reason from a few steps in a series to the whole series, partly because of the occurrence of critical points, and partly from the development at the extremes of new and unsuspected powers. Sir John Herschel remarks, that until very recently 'the formulæ empirically deduced for the elasticity of steam, those for the resistance of fluids, and on other similar subjects, have almost invariably failed to support the theoretical structures that have been erected upon them.'

The method of Concomitant Variations is powerful in suggesting, as well as efficacious in proving, causal connexions. The mind is apt to be aroused to the bond between two circumstances by encountering several conjunctions of the two in unequal degrees. Very often, we are not alive to a connexion of cause and effect till an unusual manifestation of the one is accompanied with an unusual manifestation of the other. We may be using some hurtful article of food for a length of time unknowingly; the discovery is made by an accidental increase of quantity occurring with an aggravation of some painful sensation. This is one form of the efficacy of an Extreme Case; an efficacy felt both in science and in rhetoric.

A remarkable case of Concomitant Variations is furnished by the discovery of a connexion between the solar spots and the positions of the planets. Thus, as regards Venus, 'spots are

nearest to the solar equator when the heliographical latitude of Venus is 0°,' and obversely.

An important device for discovering, and also for proving, laws of causation, consists in arranging things possessing a common property in a serial order, according to the degree of the property. Thus, we may arrange bodies according to their Transparency or Opacity, according to Specific Gravity, to Conduction of Heat and Electricity, and so on. We are then in a position to detect any corresponding increase in some accompanying property, and thereby to establish a law of concomitance or causation. This method is designated, by Mr. Mill, Classification by Series, and by Sir G. C. Lewis, the Method of Continuous Comparison. The progress of Life in the animal scale; the progress of mental development in human beings; the progress of civilized institutions, as Government, Judicature, the Representative System,—may be expressed in a series, so as to trace concomitant variations.

It is greatly to be desired that, in Physical Science, all the substances in Nature should be set forth in distinct tabulations, according to the degree of every important property. It was when transparent bodies were arranged in the order of their refracting power, that the connexion was discovered between high refracting power and combustibility.

METHOD OF RESIDUES.

6. The canon of Residues is :— Subduct from any phenomenon such part as previous induction has shown to be the effect of certain antecedents, and the residue of the phenomenon is the effect of the remaining antecedents.

After a certain progress is made in the inductive determination of Causes, new problems are greatly simplified by subducting from a complex sequence, the influence of known causes. Sometimes this of itself may amount to a complete elimination. Such procedure is styled the Method of Residues. It is an instrument of Discovery as well as of Proof.

The method is symbolically illustrated thus :—Suppose the antecedents A B C followed by the consequents *a b c;* and that by previous inductions, we have ascertained that B gives *b*, and C gives *c*. Then by subtraction, we find A to be the cause of *a*. The operation is substantially the method of Difference, and has all the decisiveness belonging to that method.

Sir John Herschel was the first to show the importance of studying residual phenomena. His examples are very strik-

ing (Introduction to Natural Philosophy, p. 156). Thus, the retardation of the comet of Encke has been the means of suggesting, and may ultimately suffice to prove, the existence of a resisting medium diffused throughout space. Again, the observation of Arago—that a magnetic needle, set a vibrating, is sooner brought to rest when suspended over a plate of copper —was the first clue to the discovery of Magneto-Electricity.

The anomalies in the motion of Uranus led Adams and Le Verrier to the discovery of Neptune.

The study of the electrical odour was the first step to the discovery of the remarkable substance—Ozone.

Sir G. C. Lewis remarks that 'the unforeseen effects of changes in legislation, or of improvements in the useful arts, may often be discerned by the Method of Residues. In comparing statistical accounts, for example, or other registers of facts, for a series of years, we perceive at a certain period an altered state of circumstances, which is unexplained by the ordinary course of events, but which must have some cause. For this *residuary phenomenon*, we seek an explanation until it is furnished by the incidental operation of some collateral cause. For example, on comparing the accounts of live cattle and sheep annually sold in Smithfield market for some years past, it appears that there is a large increase in cattle, while the sheep are nearly stationary. The consumption of meat in London may be presumed to have increased, at least in proportion to the increase of its population; and there is no reason for supposing that the consumption of beef has increased faster than that of mutton. There is, therefore, a residuary phenomenon, viz., the stationary numbers of the sheep sold in Smithfield—for which we have to find a cause. This cause is the increased transport of *dead meat* to the metropolis, owing to steam navigation and railways, and the greater convenience of sending mutton than beef in a slaughtered state.'

The question as to the existence of a special force of Vitality—the vital force, or the vital principle—takes the form of an enquiry into a residuum. We have first to make allowance for the operation of all the known forces of inorganic matter; and when these have been exhaustively computed, the remainder may be set down to a special influence, or vital principle. For anything we know at present, the *inorganic* forces, operating in *the special collocations* of organized bodies, may be competent to produce all the observed effects.

The only proof of an exhaustive Analysis, whether in

material actions or in mental processes, is there being nothing left. Thus, in the Human Mind, it is disputed whether there be a separate and unique faculty, called the Moral Faculty, or the Moral Sense. Now, there can be no doubt as to the presence of common elements of Feeling, Will, and Thought, in our moral judgments and actions; as, in the case of the vital principle, the question is, what remains, when these are all allowed for. The same application of the Method of Residues occurs in the controversy as to Instincts, and Innate Ideas; does Experience, concurring with the usually admitted Intellectual Powers, account for the whole of the facts?

CHAPTER VII.

EXAMPLES OF THE METHODS.

√ The Experimental Methods have been regarded mainly as instruments of Elimination and Proof, or of separating irrelevant accompaniments from causal accompaniments. In their working, however, they unavoidably lead to inductive generalizations, in which aspect they are methods of Discovery. The same search for instances, the same comparison of them when found, both conduct us to new principles or laws, and prove them when once attained. Still, it was not desirable to keep up the double illustration throughout. In the miscellaneous examples that are to follow, occasional allusion will be made to the procedure suited to the discovery of generalities.

The proofs adduced to show that the mode of action, in Smelling, is Oxidation, may be quoted in illustration of the Methods. The phenomenon is one of great interest, and of some perplexity. The following important facts were indicated by Graham.

The sweet odours are due to hydro-carbons, as the ethers, alcohol, and the aromatic perfumes. Now, all these substances are highly oxidizable at common temperatures, being speedily decomposed in the air. Again, sulphuretted hydrogen, the most familiar of malodorous substances, is readily oxidized, and is destroyed in that manner. These are instances of Agreement (in presence).

A farther instance of Agreement is shown in the decomposition of hydrogen compounds, in the act of causing smell. When a small quantity of seleniuretted hydrogen is inhaled by the nose. the metallic selenium is found reduced upon the lining membrane of the cavities. The sensation is an intensely bad smell.

A remarkable case of Agreement in Absence is furnished by the marsh gas—carburetted hydrogen. This gas has no smell. As the proof of the concurring absence of its oxidation at common temperatures, Graham obtained it from the deep mines where it existed, for geological ages, in contact with oxygen. Again, hydrogen itself, if obtained in purity, has no smell; and it does not combine with oxygen at the usual temperature of the air.

An instance approaching to Difference is the following. If oxygen is excluded from the cavities of the nose, there is no smell. Also, a current of carbonic acid arrests the odour; an influence which may (although not with absolute certainty) be supposed hostile to oxidation.

To make the evidence complete, it is requisite that all the instances of the effect should be of the same unvarying tenor, or that there should be no exceptions. Until every apparent discrepancy is reconciled, the facts are inconclusive. A seeming exception is the pungency of *ozone*, which is looked upon as a more active form of oxygen. Now we can hardly suppose that ozone combines with oxygen; a more likely supposition is that, by its superior activity, it combines with the nasal mucus.

The research into the cause of Dew has been used by Sir John Herschel, and again by Mr. Mill, as a happy example of experimental elimination involving nearly the whole of the methods. All the stages of this inductive determination are highly instructive.

The first point is to settle precisely the phenomenon to be explained. This is an exercise of Definition, and can never be too rigidly attended to. There is some danger, in the present case, of confounding the effect with certain other effects; and hence the expediency of defining by an exhaustive *contrast.* Well, Dew is moisture; but that moisture is *not* rain, and *not* fog or mist; it is moisture spontaneously appearing on the surface of bodies when there is no visible wetness in the air. In a perfectly clear and cloudless night, there may be a copious moisture on the surface of the ground, and this moisture is the thing to be accounted for.

Now, the problem being given as an effect, with the cause unknown, we cannot make experiments, until a cause is suggested. This is a pure effort of Discovery, preparatory to the application of the methods of inductive proof. On the various occasions when dew appears, we must look out for the attendant circumstances, with a view to their successive elimination. We know, for example, that dew appears chiefly at night, which would suggest some of the circumstances connected with night-fall, as darkness, cold, and any of the concomitants of these. That darkness is not the cause could be shown if either dew appears before sunset, or if it ever fails to appear at night. As the last alternative is very frequent, we must, so far as the Experimental Methods are concerned, pronounce against darkness There would then remain the agency of Cold.

Farther, in this preliminary stage of looking out for a possible cause, we need not confine ourselves to the actual phenomenon. In the conduct of the research, as recorded, much stress was laid upon the reference to *analogous* effects, or to other cases where moisture spontaneously appears on surfaces, in the absence of visible wet. All such analogies are valuable for suggestion or discovery, in the first instance, and for proof afterwards. They are these:—(1) the moisture that gathers on cold stone or metal when breathed upon; (2) the moisture on the outside of a tumbler of spring water fresh from the well in hot weather; (3) the moisture that often appears on glasses when brought into a hot room full of people; (4) what appears on the inside of windows when a room is crowded, and during changes in the outside temperature, (5) what runs down our walls, especially outer passages, when a warm moist thaw succeeds to frost. All these cases correspond to the definition; and their comparison is likely to indicate some circumstance to be subjected to experimental elimination. To take the first instance—the breath upon a cold metallic surface; the warmth of the air and the coldness of the surface are obvious accompaniments. Some of the others would suggest the same conjunction, while all are compatible with it. Now, this is the situation already suggested by the original phenomenon, the dew at night-fall. Consequently, we are in a position to proceed experimentally; we can try the cooling down of surfaces under variation of circumstances.

An easy experiment will tell us whether the cooling of the surface be a uniform fact, in the production of dew. Lay a thermometer on the dewed grass, hanging another in the air;

and repeat this on many successive nights. The actual result is that whenever a surface is dewed, it is colder than the air around it. This is a proof from Agreement; but proofs from Agreement, unless they can be multiplied through all nature, in all climes, seasons, and situations, will not of themselves decide either causation, or universal coincidence.

By varying the circumstances, we can bring to bear the other methods. We may, for example, try Agreement in Absence; that is, make the same appeal to experiment in nights where there is no dew anywhere. The phenomenon, however, would be found to evade this test; there would be cases of actual cooling of surfaces below the temperature of the air, and yet without dew. Hence the necessity of a different course of proceeding.

Observation reveals to us the fact that on the same night, and in the same spot, some surfaces are dewed, and others not. This holds out the prospect of an appeal to the Method of Difference. On the surface of a plate of glass, there may be dew, while on a polished metallic surface, there is none. Unfortunately, however, such a couple is not suited to the canon of Difference. The points of diversity between glass and metal are too numerous to comply with the stringent requisite of that canon. We must, therefore, shift our ground once more.

It being apparent that the nature of the *material* enters into the effect, let us expose a great variety of different materials—metals, glass, stone, wood, cloth, &c. We now find that there is a scale of degree; between the extremes of no dew and copious dew, there is a gradation of amount. The enquiry then arises, is there any other property of these different materials varying in concomitance with their being dewed? Does their temperature (which is the clue that we are going upon) change in exact accordance with the amount of dew? There was here scope for a direct appeal to the thermometer. We have not, however, to record the issue of such an appeal; the history of the research pursues another and more circuitous route for arriving at the conclusion. It so happened, that the experiments, begun by Sir John Leslie, upon the conduction and the radiation of heat, came in to the aid of the present enquiry; and the use made of these is sufficiently illustrative of the canons of Elimination. It appeared, on the comparison of the various materials, that the rate of becoming dewed varies inversely with the *conducting power* of the substance; the good conductors—the metals—are not dewed, the bad conductors are dewed according to

their badness as conductors. This is the method of Concomitant Variations; what it points to will be seen presently.

It is next desired to ascertain how far difference of *surface* operates, material being the same. The comparison shows that rough surfaces are more dewed than smooth, and black more than white. Instead of the direct test of the thermometer, the appeal here also is to Leslie's experiments on the radiation of heat from surfaces; those surfaces that are most dewed—rough and black—are the best *radiators* of heat. The interpretation of this will be taken with the foregoing.

In the meantime, make another variation, namely, for *texture;* compare the compact textures of metal, stone, wood, velvet, eider-down, cotton, &c.; the compact bodies are little dewed, in the comparison, the loose bodies, much. Now, as regards heat, the loose bodies are very *bad conductors;* they resist the passage of heat through them, and are therefore chosen as clothing.

Let us now seek the interpretation of these three last results of Concomitant Variations. The first and third relate to bad conduction of heat as a concomitant, the second to good surface-radiation. Now, both circumstances point to one result, that is, *surface cooling*, in a cold atmosphere. A surface is cooled down by a cool contact, but if heat is rapidly supplied from within (which is good conduction) the lost heat is made good, and the fall of temperature is delayed, until the interior has cooled also. In bad conductors, the loss is not made good in the same way, and the surface temperature falls. Thus, bad conductors sooner become superficially cold, in a cold atmosphere. Next as to Radiation. The explanation here is still more easy. Good radiation is, by implication, surface cooling; bad radiation, as from a polished metal surface, is retention of surface heat. We thus come round to the conclusion, which a series of trials by the thermometer would have given at once, namely, that surfaces become dewed exactly as they fall in temperature. To all appearance, therefore, we have established a link of connexion between cooling and dew.

The appearance is not the reality. There is still outstanding the fact that the same fall of surface temperature will not always bring out dew. Neither the same absolute surface temperature, nor the same difference between the surface temperature and the air temperature, is constantly followed by a deposit of moisture. We have here obviously a *residual* circumstance, whose investigation should next follow. The instances where the same thermometric difference is unattended with dew need to be studied by exactly the same routine as

has now been followed. We must look out for the suggestion of a possible agency; and next subject that to experimental trial, with a view to proof or disproof. This residuum would have given rise to a very arduous research if it had been left to experimental determination. The difficulty was conquered in another way. Already (1799) had Dalton published his theory of Aqueous Vapour, or the Atmosphere of Steam, which was the missing link in the explanation of Dew. His positions were—that the aqueous vapour contained in the atmosphere is variable in amount, according to circumstances, and that the amount is limited by temperature. To each degree of temperature corresponds a certain amount, which is the saturation of the air at that temperature. An amount equal to one inch of mercury is sustained at 80°, half an inch, at 59° Supposing the air saturated at any one moment, a fall of temperature will lead to precipitation as visible moisture; but as the air is not always saturated, a fall of temperature will not bring dew or mist, unless the fall extends below the degree corresponding to saturation, called the temperature of the Dew-point. This is the residual circumstance, the thing wanted to complete the proof of the connexion of dew with surface coldness.

The present instance is a case of Cause and Effect; as may be shown in various ways. In the way that the case has been stated, there is not apparent any *transfer of energy*, which is the best criterion of causation; but underneath the appearance, we find there is such a transfer. Heat is necessary to convert water into steam, and this conversion is an instance of the transmutation of power according to a definite rate of exchange. The withdrawal of the heat is followed by the re-collapse of the invisible vapour into water or visible moisture. So that the production of dew is clearly a sequence under the great law of transferred energy. Other proofs of causation are dispensed with by this decisive consideration. Mr. Mill, however, remarks, as a distinct criterion of cause and effect, as well as a means of settling which is cause, and which is effect, that cooling is a consequence of known and independent antecedents, and therefore cannot be set down as consequent on the occurrence of dew.

The next example is of value as showing the Experimental Methods in their purity, or in the absence of all deductive applications of laws, such as completed the enquiry into the cause of Dew.

On the 16th of May, 1861, Dr. Brown-Séquard delivered the Croonian Lecture before the Royal Society, and took for his subject the 'Relations between Muscular Irritability, Cadaveric Rigidity, and Putrefaction.' In this he adduced facts to maintain the following position:—

'*The greater the degree of muscular irritability at the time of death, the later the cadaveric rigidity sets in and the longer it lasts, and the later also putrefaction appears and the slower it progresses.*'

By muscular irritability is meant muscular power or aptitude for contracting. A man fresh in the morning for his day's work would be said to have a good store of muscular irritability: at the end of the day's work, the stock is comparatively exhausted. It would of course be still more exhausted after protracted fatigues continued through many days.

The cadaveric rigidity is a stiffening of the muscles that occurs in all animals some time after death. The time when the stiffening begins, and the duration of it, are variable, and Dr. Brown Séquard tries to establish the law or cause or condition of this variation. This he does by a series of observations, whose force will be appreciated by noting how far they comply with the exigencies of the experimental methods.

First set of Experiments.—Paralyzed muscles. Here he has two connexions to establish, in order to the end in view. He first shows that the paralysis of a muscle leaves it for a time with more irritability than the unparalyzed or exerted muscles. He paralyzed the muscles of one leg in a dog, by section of the nerve. Five hours afterwards the dog is killed (by asphyxia). In the paralyzed muscles the irritability lasted *ten* hours; that is, it was possible to induce contractions in them (by stimulants) up to that time. In the healthy leg, the irritability lasted only *four* hours; in other words was very much less. Now compare the results as regards Rigidity and the delay of Putrefaction—

	Duration of irrit.	Duration of rigidity.	Putrefaction commenced.
Paralyzed M.	10 hours	13 days	17th day.
Healthy "	4 "	5 "	7th "

Here then is an experiment clearly of the nature of Difference; for two legs of the same animal were compared, and the only difference was the paralysis of one of them. It is true, as in all cases of vivisection, that an experiment of Difference must always be received with caution, seeing that

other changes may be made by the means taken to produce the difference. Yet, at all events, here is a strong presumption.

The doctrine is confirmed farther by another aspect of the paralysis. If an animal is allowed to live a month after paralysis of a member, the paralyzed muscles are then inferior in irritability, and when compared under those circumstances, they become rigid and putrefy sooner.

Second set of Experiments.—Effects of diminution of temperature upon muscles.—Dr. Brown-Séquard had determined, by previous experiments, that cold increases the vital properties of the nerves and muscles—a fact on which the stimulating power of cold upon the animal system depends. He now applies this fact to the enquiry in hand.

Two kittens of the same litter were placed in different temperatures. After death, the following differences were discernible. The one, kept at a temperature of 98°.6, assumed the rigidity in $3\frac{1}{2}$ hours; this lasted three days, putrefaction commencing in the fourth. In the other, which had been kept so cool, that a thermometer inserted in the rectum stood at 77°, the rigidity was delayed till the 10th hour, and lasted nine days, putrefaction commencing on the tenth. This experiment was repeated with many animals, and is also an experiment according to the Method of Difference. This is the general principle of the fact known in hot climates, that the dead putrefy almost immediately after death, and must be interred without a moment's delay. The relaxation of the vital powers in hot climates is only a part of the same fact. The full explanation of this point, or the resolution of the law into still higher laws is not yet fully made out.

Influence of death by lightning and galvanism. — It was thought by John Hunter that animals killed by lightning did not stiffen. This has been found not the case. Still there are instances where the rigidity has either not set in, or been of so short duration, that its existence has not been traced. Lightning may kill in various ways :—1st, By fright; 2nd, By hæmorrhage; 3rd, By concussion of the brain. In all these three modes, there ought to be a manifestation of the rigidity. But there is a fourth mode, which is to convulse all the muscles so violently as utterly to exhaust their irratibility; in which case the rigidity may fail to be noticed. This is the way that galvinism acts upon animals.

Experiments were accordingly tried by galvanizing the limbs of Rabbits; comparing the galvanized with the ungalvanized limbs, with respect to the time of rigidity.

	Galvanized Limb.	Not Galvanized.
Duration of Irritability,	7 to 20 minutes.	120 to 400 min.
,, of Rigidity,	2 to 8 hours.	1 to 8 days.
Putrefaction advanced,	within a day.	After several days.

The experiments were repeated on dogs with the very same results.

Also, guinea-pigs were subjected wholly to galvanism, but in different degrees. In those powerfully galvanized, the irritability lasted a short time, and the rigidity was corresponding rapid and brief. With a less degree of galvanism, the time of both phenomena was protracted. We have, therefore, an additional corroboration of the law, still by the powerful Method of Difference.

Influence of prolonged muscular exercise. — This, of course, is a cause of diminished irritability. Now, there are well-ascertained facts that connect prolonged exertion with rapid putrefaction. Over-driven cattle and animals hunted to death putrify speedily. So in cocks killed after a fight. Soldiers killed in a very prolonged fight show the same phenomenon. The rigidity is quickly over, and the putrefaction rapid.

These are instances of the Method of Agreement.

Influence of nutrition on muscles.—Dr. Brown-Séquard here collects confirming instances, from the comparison of cases where death happens in a well nourished condition of the muscles, with cases where death had been preceded by inanition. Thus, when men strong and fresh have been killed suddenly, the rigidity and putrefaction have appeared very late. A case is recorded of muscular irritability continuing twenty-six hours in a decapitated man. Here is Agreement in presence. Compare those instances with others of persons dying of slow exhaustion, and the appearance is reversed. A man dying of prolonged typhoid fever, for example, was found to show no trace of rigidity, and putrefaction commenced in less than an hour. This is Agreement in Absence.

Influence of Convulsions on rigidity and putrefaction.—It appears that muscles much attacked with cramps before death speedily give way to putrefaction.

Certain *poisons* (as strychnine) sometimes produce convulsions before death, and in those cases the rigidity and putrefaction progress rapidly.

Such is an ample body of evidence from observation and experiment to establish the position laid down. The Methods of Agreement, of Difference, the Joint Method, and the Method of Variations, have been all brought into play. And if there

are any doubts about the decisiveness of the experiments on the Method of Difference, from the possibility of making other changes besides the one intended, these doubts are dispelled by the coincidence of results from so many distinct experiments. The research is purely Inductive No consideration of a Deductive kind has been introduced; although there are general considerations that give great probability to the conclusion. Muscular irritability is the living condition of the muscle—its vitality—which may be greater or less; and the greater it is, the longer the muscle will retain its living characters, or the longer it will be in passing to the characters of death, which are rigidity and putrefaction. These, therefore, are delayed by fulness of vitality; while loss of vitality hands the system over all the sooner to the destroyer.

When we form conclusions, on an insufficient employment of the methods of elimination, we commit Fallacies of Induction. Of these, numerous examples might be given, and the proper place for them is in the course of the exposition of the Methods themselves. As it is still the custom, however, to retain, in works of Logic, a separate chapter or book on Fallacies, we shall reserve for that part of the subject, the instances of Inductive fallacy.

CHAPTER VIII.

FRUSTRATION OF THE METHODS.

1. In the Inductive Methods as hitherto contemplated, two conditions have been supposed; first, that an effect has only one cause, or set of antecedents; secondly, that different effects are kept apart and distinguishable. Both conditions may be wanting.

In the method of Agreement, for example, it is assumed, that the effect *a* has only the cause A; should A and C *both* be causes, the method would be defeated. The absence of A would not prove that it is not a cause; for the effect might still be due to C. The special difficulties attending this case must now be considered

Again, the effects $a\ b\ c$ are supposed to stand out distinguishable. They may, however, be fused or united in one simple effect $2\ a\ c$, or $3\ a$. This is the Intermixture of Effects; and is still more baffling to the inductive methods, as hitherto given.

PLURALITY OF CAUSES.

2. In many instances, the same effect is produced by a PLURALITY OF CAUSES: as Motion, Heat, Pleasure, Death.

Bodies are put in motion by all the different agencies termed Prime Movers—animal strength, wind, water, steam, combustion (as in gunpowder), &c. Finding a body in motion, therefore, we cannot ascribe it to any special agent, merely from the fact that it is in motion: we see a wheel turning and doing work, but we may not be able to attribute its motion to one agent rather than another. In like manner, there are various sources of Heat; the solar ray and combustion are the most familiar; but friction and electricity are also sources. Hence the fact of the evolution of heat does not point out the cause; as an example, uncertainty still attaches to the immediate antecedent of animal heat.

There are numerous causes of pleasure and of pain: numerous modes of stimulating the nervous system; numerous agencies of good health and of bad health; numerous ways of getting a livelihood; numerous causes of death.

It is to be noted, however, that the plurality in some of these instances is on the surface only. As regards Motion, the law of the Persistence of Force assigns a common origin to all the so-called prime movers, these, therefore, are *proximate*, and not the ultimate sources. The same law covers the production of Heat, however various the apparent antecedents. The causes of Pleasure can be generalized into a small number of agencies, if not into one. Possibly all stimulants may, in the last analysis, be found to have a common effect on the substance of the nerves. The ways to Wealth may be apparently many, but we can cover them all by one general expression,—earning and saving. In Health and Sickness, there might possibly be generalized expressions of the many proximate causes. So with Death.

Nevertheless, for practical purposes, we have to ascertain not simply the primal cause, but the special embodiment of that cause, on a certain occasion. It is not enough, when a man is found dead, to assign the stoppage of the heart, or of

the lungs, or the extinction of the vital forces; we desire to know in what form and circumstances these generalized causes were specialized; whether by cold, by inanition, by poison, by mechanical violence, or otherwise.

3. The chief consequence of Plurality of Causes is to frustrate the Method of Agreement.

The Method of Difference remains intact. Whatever be the plurality of causes of motion, if we observe the introduction of some one agent followed by the effect, we know the cause in that instance. There may be many ways of keeping up the animal heat, but the transition from the temperature of 60° to 30°, by causing an immediate sense of chilliness shows that the external temperature is essential to comfortable warmth on that particular occasion.

The operation of Plurality is to give uncertainty to the Method of Agreement. For example, we observe numerous cases of unhealthy human beings whose parents were unhealthy; this would be to a certain extent a proof from Agreement. On the other hand, many unhealthy persons are the children of perfectly healthy parents; whence, concluding by the strict rule of Agreement, we should affirm that unhealthiness in the parents is in no case a cause of unhealthiness in the children; that the two facts are not in any way connected as cause and effect. The conclusion is obviously wrong; it would be correct were there only one cause of ill health; it is illegitimate if there be many causes.

Plurality is illustrated by our English spelling. The method of Agreement is nullified in this instance. In certain words, the letters *ough* agree with a peculiar sound, as in 'rough.' The same word occurs with other letters, as in 'ruff,' and the same letters occur with a different sound, as in 'bough.' Whence, by the Method of Agreement, we should infer that there was never any connexion between either sound and 'ough.' A similar illustration is afforded by ambiguous words. The word 'air' is spoken in company with a musical melody; at other times it is spoken where there is no music; any one unprepared for plurality, and following out Agreement, would conclude that the connexion with music was purely casual; that there was no fixed bond of union between the two. We acquire the meanings of the vocables of our language chiefly by the method of Agreement. We gradually eliminate all accompaniments that may be absent consistently with the employment of each word. We find, after a number of

repetitions of the word 'fire' in various connexions, that the one fact common to all is blazing combustion with heat. We learn in course of time to extend the word to metaphorical significations. These being conjunctions of pure co-existence, without causation, they cannot be dealt with by any other method, while the occurrence of plurality, even when understood and allowed for, is a serious and painful distraction to the inductive process.

Again, pressure on the brain is a cause of insensibility; yet, as we find insensibility where there has been no pressure, we should say, according to Agreement, that pressure is not a cause. In the same way, every one of the causes might be proved not to be a cause—deficiency of blood, excess of dark unhealthy blood, rupture of the nervous continuity, &c.

Extraordinary facts have come to light showing the possibility of exerting the mental powers, under disease of very large portions of the brain. These facts would seem to prove that such parts have no share in the mental functions. The safer inference is that there is a plurality of nervous seats or tracks for the same functions. It has long been supposed that the two hemispheres have common functions.

The discussion of the problem of Beauty is often rendered fruitless by the neglect of Plurality. The attempt is made to assign some one circumstance present in all beautiful things—as Colour, Harmony, Fitness, Unity, Suggestion of Mental qualities. Now, by the unqualified method of Agreement, every assignable circumstance could be disproved; with reference to each one in turn, would it be possible to find objects of unquestioned beauty where that one is not present. Jeffrey thinks it a sufficient refutation of the theories he opposes, to produce beautiful objects where the alleged source of beauty is absent.

¶ 4. The counteractives to the failure of Agreement, in the case of Plurality, are (1) great multiplication of instances, and (2) Agreement in *absence*, that is, the Joint Method.

(1) One remedy for the failure of the Method of Agreement, under Plurality, is *multiplication of instances*. This will operate in various ways. It will tend to bring out all the causes; which is one desirable issue of Plurality. An extended statistics of Crime or Pauperism will show us the possible agencies, by giving a wide scope for elimination. The long experience of medical practitioners has taught them

nearly all the possible causes of the greater number of diseases. At this stage of exhausted plurality, the only point for enquiry, in the special instance, is—Which of the causes are present, and are these free to operate? Knowing, all the contributing causes of Pauperism, we ask which of these occur in England, in Ireland, or in Scotland, and are they free or uncounteracted? Being aware of the various antecedents of dyspepsia—bad food, too much food, too little food, hard labour, want of exercise, intemperance, mental wear and tear, bad air, a hot climate, &c.—we can judge what brought on the disease in a given instance.

If we do not know which causes are present on a given occasion, and whether those actually present are counteracted, mere Agreement is wholly fallacious. The fallacy named *post hoc, ergo propter hoc*, is an abuse of Agreement, where elimination is vitiated by Plurality, as in a great number of political inferences. It is remarked that Protestantism is accompanied with superior industry; the instances attainable are insufficient in number to eliminate other causes.

(2) The other remedy is the Joint Method. We should seek out cases of Agreement in *absence*, which are of a very decisive nature. If in all cases where a particular effect fails, one particular cause is absent, there is, in spite of possible plurality, a strong presumption that the two circumstances are cause and effect in those instances. The reason grows out of that close approach to the Method of Difference furnished by Agreement in absence. Although there are various causes of light, yet the union of agreement in presence with agreement in absence is sufficiently decisive of the connexion of light with a high temperature. The special connexions of light with *low* temperature are not denied; they are admitted as exceptions to agreement in absence, as a *residuum* to be accounted for. We know one cause thoroughly; we find there are other causes, as yet imperfectly known, which have this uncertainty, namely, that a body at the common temperature of the air may possibly be luminous.

THE INTERMIXTURE OF EFFECTS.

5. The Methods of Elimination suppose different effects to remain separate and distinguishable; whereas cases arise where the effects of different causes unite in a homogeneous total.

When, in an aggregate phenomenon, distinguishable ante-

cedents produce distinguishable consequents—A B C giving *a b c*, and A D E giving *a d e*, the experimental methods operate to advantage. The combination of wind, rain, and increased temperature, produces a combination of distinguishable effects—waves on the surface of water, flooding of streams, the sensation of warmth.

In other cases, and these very numerous, the effect of the several causes is homogeneous, and is merely increased in amount by the concurrence. The sea is fed by innumerable rivulets. The wind often concurs with tidal agency, so as to produce a higher tide. A body propelled by several prime movers, as when a train is urged by three locomotive engines, shows only one effect, velocity of movement. The moon's path is a resultant of the attractive forces of the sun and the earth combined with its projectile movement. The path of a comet is the resultant of many influences; it does not bear on the face of it the story of them all. An invalid repairs to some salubrious spot, and plies all the means of restoration to health; many influences combine to the result, but the effect is one and indivisible.

A still more perplexing situation is the conflict of opposing agencies. In an equal balance nothing is seen, and yet great powers have been at work. In unequal contests there is an effect; but that effect does not suggest the fact of conflict. A trader has a net profit at the end of the year; the statement of that profit, however, gives no information of his expenditure and receipts. The patient may be under various healthy stimulants, each working its proper effect; but some one noxious agency may counteract the whole.

Natural agencies can never be suspended; they may be counteracted by opposite agents. The force of gravity is not interfered with when a balloon rises, it is merely opposed by a greater force; it still operates but in a different form. Instead of causing the usual appearance, namely, the descent of bodies to the ground, it operates to diminish the effect of an upward force, the buoyancy of the air (itself an indirect consequence of gravity).

A counteracted force is technically said to exist in *tendency*. There is a tendency in all bodies to descend to the ground; in water to find its level; in the moon to move towards the earth, and towards the sun. There is a tendency in human beings to seek their own interest; in despotic sovereigns to abuse their power. The tendencies are not annihilated when they fail to be realized; they are only counteracted by some opposing tendencies.

A farther circumstance working to invalidate the operation of the methods is the *mutuality of cause and effect.* In political causation, this is illustrated by Sir G. C. Lewis as follows :—'It happens sometimes that when a relation of causation is established between two facts, it is hard to decide which, in the given case, is the cause and which the effect, because they act and re-act upon each other, each phenomenon being in turn cause and effect. Thus, habits of industry may produce wealth ; while the acquisition of wealth may promote industry : again, habits of study may sharpen the understanding, and the increased acuteness of the understanding may afterwards increase the appetite for study. So an excess of population may, by impoverishing the labouring classes, be the cause of their living in bad dwellings ; and, again, bad dwellings, by deteriorating the moral habits of the poor, may stimulate population. The general intelligence and good sense of a people may promote its good government, and the goodness of the government may, in its turn, increase the intelligence of the people, and contribute to the formation of sound opinions among them. Drunkenness is in general the consequence of a low degree of intelligence, as may be observed both among savages and in civilized countries. But, in return, a habit of drunkenness prevents the cultivation of the intellect, and strengthens the cause out of which it grows. As Plato remarks, education improves nature, and nature facilitates education. National character, again, is both effect and cause ; it re-acts on the circumstances from which it arises. The national peculiarities of a people, its race, physical structure, climate, territory, &c., form originally a certain character, which tends to create certain institutions, political and domestic, in harmony with that character. These institutions strengthen, perpetuate, and reproduce the character out of which they grew, aud so on in succession, each new effect becoming, in its turn, a new cause. Thus, a brave, energetic, restless nation, exposed to attack from neighbours, organizes military institutions ; these institutions promote and maintain a warlike spirit ; this warlike spirit, again, assists the development of the military organization, and it is further promoted by territorial conquests and success in war, which may be its result—each successive effect thus adding to the cause out of which it sprung.' (Methods of Politics, I. p. 375).

6. The Intermixture of Effects is a bar to the Experimental Methods.

If A B C D conspire to yield, not $a\ b\ c\ d$, but a; and if A B C F yield still a, nothing is eliminated, there is no progress. If a were precisely measurable, and if its variations corresponded definitely to the removal of particular agents, the Method of Difference would cope with the case: the omission of A followed by the reduction of a to $\frac{3}{4}\ a$, would be a proof that A produced $\frac{1}{4}\ a$. But the Method of Agreement, in its proper character of varying the circumstance by excluding some agents and including others, could not furnish a decisive proof, so long as a represented the sum of several effects.

Now, as in many departments, effects are thus inextricably blended, we should be at a stand-still, were we not in possession of some method more searching than Agreement. Even in the Inorganic Sciences, as Mechanics and Chemistry, we have this complication; in Biology, Mind, and Society, we have it still more. A good crop is a single effect; the agency may be multifarious. A voluntary action may be the resultant of several motives. The rise and fall of prices, the general prosperity of a country, the increase of population, seldom depend on one cause exclusively; yet the effect in each case is, to our eyes, homogeneous.

Concomitant Variations is the only one of the Methods that can operate to advantage in such cases. If a cause happens to vary alone, the effect will also vary alone, and cause and effect may be thus singled out under the greatest complications. Thus, when the appetite for food increases with the cold, we have a strong evidence of connexion between those two facts, although other circumstances may operate in the same direction.

The assigning of the respective parts of the sun and moon, in the action of the Tides, may be effected, to a certain degree of exactness, by the variation of the amount according to the positions of the two attracting bodies.

By a series of experiments of Concomitant Variations, directed to ascertain the elimination of nitrogen in the human body under varieties of muscular exercise, Dr. Parkes obtained the remarkable conclusion, that a muscle grows during exercise, and loses bulk during the subsequent rest.

For the first of the difficulties now illustrated—Plurality, with the aggravation of counteracting influences—an important instrument remains, an additional Method of Elimination, termed 'Elimination by the Computation of Chance.' For

dealing with the same uncertainty, and for the still greater (and often accompanying) uncertainty of Intermixture of Effects, the chief resort is to DEDUCTION The two next chapters will be occupied with those two subjects.

CHAPTER IX.

CHANCE, AND ITS ELIMINATION.

1. An important resource in eliminating the irrelevant antecedents or accompaniments of an effect is obtained through the calculation of Chance or Probability.

This is to approach the problem of Induction from a novel aspect. Instead of varying the circumstances so as to procure the absence of the several antecedents A B C in turn, we consider whether these agents might not be present of themselves without any regard to the effect in question. Thus, a person dies at midnight, when the sun is below the horizon and due north. Now, seeing that this event happens every twenty-four hours, as a consequence of cosmical operations, it must come round and must coincide with a great many things that happen on the earth. The fact of such coincidence is not of itself held as proving causation or regular concomitance with everything that happens at that time. Before we presume a concurrence of causation between two coinciding things, we enquire whether the two things are not equally liable to concur, whether connected or unconnected.

The night that Oliver Cromwell died, a great storm devastated London. The coincidence might affect the minds of the superstitious, but there was no proof of causal connexion. Each event grew out of its own independent series of causes and conditions; the one was a consequence of the bodily constitution and manner of life of Cromwell; the other was a consequence of the laws of the atmosphere. They concurred in time, and that is all that should be said regarding them.

Every event of every man's life must concur with some one position of the planets, on the supposition of their being no connexion whatever. Hence, such concurrences prove nothing at all; they are left out of account without even the trouble of elimination

There are certain cases, where a cause fails to produce its effect, being counteracted by some other cause. A B C is followed by *b c d*, from which the inference, by Agreement would be, that A is not the cause of *a*. Bark is administered to a patient in ague, but the symptoms are not alleviated. The strict application of the Method of Agreement would lead to the inference that bark does not cure ague. Yet we do not, in practice, lose faith in medicines from individual failures. We are prepared to encounter exceptions to cases of complicated causation. The question then comes, how far is this to go? How are we to be sure of causes at all, if they fail to work their effects? What difference can we draw between such instances and mere accidental concurrences?

The theory of Chances, or Probabilities, applies to both the situations now illustrated;—the dropping without the trouble of elimination what would be present whether another thing were present or not; and the proving of a causal agent, although not uniform in producing the proper effect.

2. A chance coincidence is one where there is no implied connexion of cause and effect, or one that would be the same in the absence of any such connexion.

Instances have been already given, and could be multiplied at pleasure. A person walking on the sea shore at a certain hour every day, will, on a given day, walk at low water; but the concurrence is said to be a chance concurrence, as the person's walking is not in any way regulated by the state of the tide. On the other hand, the concurrence with the time of day is not chance. There is a concurrence in both cases; the one without cause, or a matter of chance, the other with a cause, and not a matter of chance.

If it is proposed to enquire what coincidences are due to chance and what not, the method is dictated by the so-called rules of Chance.

Common sense suggests the principle of the solution. We know that low tide coincides with a certain hour of the day twice a month. If, on a long average, the coincidences of low tide and the person's walking on the shore happened exactly twice a month, we should say the relationship is casual, accidental, or without any link of causation; for on the supposition of there being no connexion, this number of coincidences might occur through the laws of tides. If, on the other hand, the two facts coincided daily, we should presume a coincidence. Moreover, even if it did not occur daily, but once or twice a

week, this would be more than chance would account for, and there would be a presumption of a causal connexion, which, however, is liable to be defeated or counteracted.

So with the connexion between the walking and the hour of the day. Suppose the person might walk at any time during fifteen hours of the day, he would, by mere chance, walk during any particular hour, once every fifteen days on a long average. If in fact, some one hour coincided with the walking only once in sixty days, there would be proof of an influence hostile to going out at that hour; if at some other hour, the walking occurred six days in seven, there would be proof of positive connexion with the said hour.

These obvious considerations are reduced to principles and rules in the logico-mathematical science called the 'Doctrine of Chances or Probabilities.'

3. The principle is as follows:—Consider the positive frequency of the phenomena themselves, and how great frequency of coincidence must follow from that, supposing there is neither connexion nor repugnance. If there be a greater frequency, there is connexion; if a less, repugnance.

This may be called the general case, as distinguished from certain modified cases to be stated afterwards.

If we find from observation (sufficiently extended to generalize the facts) that A exists in one instance out of every two, and that B exists in one instance out of every three; then, if A and B are wholly indifferent to each other—neither connected nor repugnant—the instances of A and B happening together will be (in the Arithmetic of Chances) one out of every six, on a sufficient average. If, really, the two co-exist oftener, there is connexion; if seldomer, repugnance.

By this method singly, could we determine a connexion of cause and effect in the instance of rain occurring with a particular wind, say the South-West. The experimental methods fail in such an instance. It is well remarked by Mr. Venn (Logic of Chance, p. 127) 'that in Probability we distinctly take notice of, and regard as evidence, reasons so faint that they would scarcely be called by any other name than mere hypothesis elsewhere.'

In the Chinese astronomical observations, frequent entry was made of new stars; and by far the larger number of these appeared in the milky way. The coincidences implied some law of connexion, but no such law was suspected by the

Chinese astronomers. We now know that the milky way contains the great mass of the stars of our galaxy; consequently all changes connected with the stars will be most numerous there. The circumstance has been adverted to as an important confirmation of the accuracy of the Chinese astronomical records.

In the generalizations of co-inhering attributes, in Physics and in Chemistry, there is often a want of perfect agreement in the details: yet the agreement is too extensive to be the product of chance, and hence we must admit the existence of a law, which, in the complications of the phenomena, is occasionally crossed and counteracted. It is a law that the alkaline bases are oxides of the metals; a remarkable exception occurs in ammonia. The law does not become waste paper because of this exception. The coincidence is one that mere chance cannot account for; and some way has to be sought out to reconcile the discrepancy. Perhaps an expression will be found that will apply alike to ammonia and to the other alkalies. The discovery of a metal in ammonia has been looked to as a solution of the difficulty.

Many genera of plants are centralized in definite geographical areas, Erica, for example; the species being collected within a certain tract, at some one point of which there is found the maximum number of species. As chance cannot account for such localizations, the endeavour is made to trace out laws of connection (cause and effect) between the plants and the locality.

In the controversies raised on the subject of Phrenology, the opponents of the system have considered that they disproved it by instancing decided exceptions to the phrenological allocation of faculties—cases of mathematicians with a small organ of number, or musicians with a small organ of tune. The facts supposed, however, are not conclusive against the system. For, in the first place, the disproof of the coincidences alleged, in respect of one or two faculties, or any number, would not disprove all the rest. But, in the second place, a few exceptions would not thoroughly disprove the alleged connexion; they would only disprove its unfailing uniformity. The phrenologist could still retreat upon the principle we are now discussing; for, if the coincidences of a certain distinguished mental aptitude,—as number, music, colour—with the unusual size of a certain region of the head, were more frequent than it would be on mere chance, or in the absence of all connexion, he would be entitled to infer a

relationship between the two. No doubt, the practical value of the facts would be very much lowered by the supposed relationship being frequently defeated; still, the bond must be considered as established. In this view, an extensive series of observations on the size and form of the human head, and on the accompanying mental qualities, if reduced to a statistics of comparative frequency, could yield indications of the localizing of mental functions, if such be the actual case.

The homœopathic maxim 'similia similibus curantur,' may be subjected to the same criticism. Exceptions do not nullify the principle, although they reduce its value as a guide. Both this and the opposite maxim ('contraria contrariis curantur') may hold in nature. The coincidences in both cases may be greater than chance would account for.

The prevalence of the different forms of Christianity after the Reformation shows a coincidence with Race that chance would not account for. The Greek church was propagated principally in the Slavonic race; the Roman Catholic church coincides largely with the Celtic race; and the Protestant church has found very little footing out of the Teutonic races. From this coincidence must be presumed a positive affinity between the several forms and the mental peculiarities of the races:—which, as an empirical law, may be applied to cases immediately adjacent, and as a derivative law (so it may be considered) may be applied still wider. We may fairly conclude, that any *speedy* conversion of one church to another is very unlikely. But the law being at best a derivative law, involving a plurality of simpler uniformities under collocations or co-efficients, may be subverted by circumstances arising in the lapse of time. It might also happen that change of place and of circumstances might defeat the law; such as emigration to other countries, or great political revolutions.

We may apply the principle to the problem of the Spread of Language. The articulate modes of the human voice being nearly the same in all races, there would be a great many common words struck out, without any communication between the races. Then it might happen too that some of these common words might be applied to the same objects, because some name or other must be applied. Of course, the probability of the same sound as the radical *ma*, being applied to the maternal parent, by different races independently, is a very small probability; and the probability of any great number of such coincidences is still smaller. Therefore, if we find in the languages of India, and of Great Britain, a very

considerable number of names almost the very same, applied to the same things, we must conclude that the coincidence is not the work of chance, and is the result of some cause.

4. A special case of the elimination of chance is presented by the combination of Chance with Law, or of casual and causal links. In a sufficiently prolonged experience, chance may be eliminated.

Thus, so far as the mere decay of the human system is concerned, deaths would be equally frequent at all periods of the year, and at all hours of the day. In the statistics of Mortality, however, we find that some months are marked by an excessive number of deaths; as December, January, and February. This points to a law of connexion between winter severity and mortality. In the same way, if we had the statistics of the deaths occurring at different hours of the day, we might find a greater number occurring in the depressing hours of the night, namely, between midnight and dawn. There is an element of chance, and an element of law; the chance can be eliminated by statistics, and the law ascertained and estimated.

The combination of chance and law is seen in the progress of the seasons. The Chance element is the fluctuation from day to day, due to meteorological changes, which, in our ignorance, we view as fortuitous. The Law is the progress of the sun, which if undisturbed would be shown in the steady increase of temperature from January to July, and reversely. The influence of the winds interferes with this regular course; but by averages taken for many years, we could ascertain for any one place the temperature proper to each day of the year, through the solar influence alone.

The skill of a player at cards is shown by his winnings at a year's end. So, the keeper of a gaming table, in spite of daily fluctuations, has a sure profit in the long run; the table being constructed with a definite percentage in his favour.

In taking observations, it is usual to multiply instances, and to strike an average. This eliminates mistakes of the senses, accidents, and all errors that do not grow out of some permanent bias.

5. A third form of the elimination of chance is the discovery of causes so small in amount as to be submerged by the casual accompaniments.

Loaded dice are detected after a long series of throws. Actual trials have shown that, in the course of 1200 throws,

there would be very nearly 200 turns-up of each side. Any great deviation from equality would be a proof of loading.

It was by the average of many daily observations of the barometer that the diurnal variations were discovered. Those periodical variations were too small to be noticed in the midst of the fluctuations from day to day; but the elimination of these last by a long course of observations brought the other to light, and gave their amount.

A small bias in an instrument might be detected by great multiplication of instances. All the chance errors would be eliminated, and would show a residuum, to be accounted for only by some permanent bias.

PRINCIPLES OF CHANCE OR PROBABILITY.

6. Probability expresses a state of the mind, and also a situation among objective facts.

As a state of the mind, it is a grade or variety of Belief. The highest degree of belief is called Certainty; the inferior degrees are degrees of Probability. The psychological criterion of strength of belief is readiness to act.

As a situation of objective facts, it points to our experience of the recurrence of events with more or less uniformity. What happens always, under certain circumstances,—as the rise of the sun, the termination of human life—is called certain; our assurance in such instances is at the highest. What happens, not always, but sometimes,—as that the sun rises in a cloudless sky, that men live seventy years—is not certain. Neither the fact, nor the failure of the fact, is certain. To this middle situation, is applied the term Probability.

At a first glance, we might be disposed to say that such events are positively uncertain; that any judgment as to their happening is incompetent; that we are in as great ignorance as to whether the sun will ever rise clear, or whether any man will live to seventy, as if we had never known the sun to rise or any man to die. In this emergency, however, we derive an aid from extended observation. If, in the same locality, we observe the rise of the sun for a great many days, we find that the rise in a clear sky happens in a certain fixed proportion, which is more and more steady as observation is prolonged. So, if we keep a record of the duration of men's lives, for a considerable period of time, we find the seventy years' lives to recur in a fixed proportion, the more steady the longer the records are extended. Hence, if it is of any value

to us to know how many days in the year the sun rises cloudless in a given climate, or how many men live to seventy, we can obtain the information with absolute certainty.

Now, there are many occasions when this knowledge of proportionate recurrences of events, or of what is called averages, is of the highest practical moment. It is needless to cite, among other examples, the system of Insurance, which is wholly built upon it.

7. When a sufficiently extended series of observations shows a fixed proportion in the relative occurrence of events, this proportion is called the Probability of the occurrence of any single event; which, however, is a fiction, meaning only the certainty of the proportion, or average, on the whole.

'If, in the run of many years, it appears that there have been, in some one place four dry days for three wet, then it is a matter of inductive certainty, that in the future that proportion will hold. We may stake any practical interest upon the recurrence of that proportion. But we are unable to say, before hand, of any one day whether it will be wet or dry. Still, a convenient fiction is used applicable to a single day. We see that the chances or probabilities are that some given day will be dry. A numerical expression is used for the degree of the probability; it is said to be four to three in favour of dryness, or against rain. This does not mean that we gain anything in a single case; a case taken apart must be held as absolutely uncertain. Unless we act upon the gross or total, we gain nothing by taking into account the numerical probabilities with a view to a single instance.

But although we are no wiser as to the individual day that we desire to be dry or wet, yet, as there are a great many similar emergencies in life, where we have to apply averages to single cases,—by following the measure of probability on all such occasions, and on all subjects, we shall be oftener right on the whole, than if we were to neglect this probability. This is the justification of our presuming that a given day will be dry and not wet, under the probability assigned.

8. It is found that the experienced recurrence of events coincides with an estimate formed thus :—Suppose that we know of several events that some one will certainly happen, and that nothing in the constitution of things determines one rather than another; in that case each will recur, in

the long run, with a frequency in the proportion of one to the whole.

Thus, in the familiar case of tossing a penny, there is supposed to be nothing in the form of the coin, or in the impulse given to it, to determine one side rather than another. In this case, every second throw will, in the long run, be heads.

So, in throwing dice, if they are fair, every sixth throw, on a long series of trials, will give ace.

An *a priori* necessity has been assumed for this proportionate recurrence of events. Such a necessity appears to be justified in the tossing of a penny; we seem to be in a state of equipoise between the two possibilities of head and tail, and feel that any inequality in the result would be without reason or cause. Accordingly, we are apt to assume, as a necessity of the case, that the turning up of head and of tail should be equally balanced at the end of a long trial. The fact is, however, that, in this and like cases, we are exceptionally circumstanced in point of knowledge; we know what are the causes at work, and that there is nothing to give a bias in the long run to either side of the penny.

In the more complicated cases, as human life, shipwrecks, fires, &c., we should not be disposed to predict anything before hand from such considerations as the above. We should not consider all years, from one to ninety, as equally open for men to die in, or that the year of age is quite indifferent. We soon come to know better; and, refraining from *a priori* supposi-positions we trust solely to induction from a sufficiently prolonged basis of actual observation.

9. The important theorems growing out of the general principles and applied to problems in Logic, are these.

I. The probability of the concurrence of two independent events is the product of the separate probabilities.

If A occur once in six times, its probability is $\frac{1}{6}$, or one for and five against; if B occur once in ten times, its probability is $\frac{1}{10}$, or one for, and nine against; the probability, or relative frequency in the long run, of the concurrence of the two is $\frac{1}{60}$—one for and fifty-nine against.

This rule is an arithmetical consequence of the general formula, and does not need a separate appeal to observation and induction. Suppose two days in three are dry, and one in three has a westerly wind, then (if the two phenomena were

independent), the chance is $\frac{2}{3} \times \frac{1}{3}$ or $\frac{2}{9}$; that is two for and seven against.

10. II. The probability of the occurrence of one or other of two events that cannot concur is the sum of the separate probabilities.

'If one man in ten is over six feet, and one in twelve under five; then in a large number, say 120,000, there will be about 12,000 over-six-feet men, and about 10,000 under-five-feet men; the sum of the two 22,000, will represent the number of such as are one kind or the other.'

11. III. The rule for the cumulation of independent Testimonies in favour of a fact, is to multiply the numbers expressing the proportionate value of each Testimony.

If a witness is correct six times out of seven, or speaks six truths for one error, his relative testimony is six for and one against, or $\frac{6}{1}$. Two witnesses of this character concurring would give a probability of 6 to 1 multiplied by 6 to 1, or 36 to 1, and so on.

12. IV. The rule for the deterioration of testimony in passing from one person to another, that is, for the weakening of traditional evidence through lapse of time, is to multiply the fractions expressing the separate probabilities.

If one witness speaks truth five times in six, the fraction is $\frac{5}{6}$; if another witness speaks truth nine times in ten, the value is $\frac{9}{10}$. If the one repeats what he has heard from the other, the testimony is weakened by the transmission to $\frac{5}{6} \times \frac{9}{10} = \frac{45}{60}$, or $\frac{3}{4}$. Of facts attested by the second witness, deriving from the first, three will be true and one false. A few such transitions bring the evidence below probability, and render it worthless. Four successive witnesses each valued $\frac{3}{4}$, would give $\frac{81}{256}$, which would be a probability against their testimony. Now, there are many cases where a testimony is not put too low by the above fraction; if a want of perfect veracity is joined with inadequate comprehension of the statement, weak memory, or other infirmity, a witness would not be correct three times in four.

The application of the Theory of Probabilities to the inductive determination of Causes is given in the following theorem taken by Mill from Laplace.

13. 'Given an effect to be accounted for, and there being several causes that might have produced it, but of whose presence in the particular case nothing is known; the probability that the effect was produced by any of these causes *is as the antecedent probability of the cause, multiplied by the probability that the cause, if it existed, would have produced the given effect.*

'Let M be the effect, and A, B, two causes, by either of which the effect might have been produced. To find the probability that it was produced by the one and not by the other, ascertain which of the two is most likely to have existed, and which of them, if it did exist, was most likely to produce the effect M; the probability sought is a compound of these two probabilities.

'Case I. Let the causes A and B be both alike in the second respect: either A or B, when existing, being supposed equally likely (or equally certain) to produce M; but let A be itself twice as likely as B to exist, that is twice as frequent a phenomenon. Then it is twice as likely to have existed in this case, and to have been the producing cause of M.

'Case II. Reversing the last supposition, let us suppose that the causes are equally frequent, equally likely to have existed, but not equally likely, if they did exist, to produce M; that in three times that A occurs, it produces that effect twice, while B, in every three times produces it but once. Since the two causes are equally frequent in their occurrence, in every six times that either exists, A is three times and B three times. But A in three occurrences produces M in two; while B in three occurrences produces M in one. Thus, in the whole six times, M is produced thrice, but twice by A and once by B. So that the probability is in favour of A in the proportion of two to one.

'Case III. Let there be an inequality in both respects. Let A be twice as frequent as B; and let A produce the effect twice in four times; B thrice in four times. Then the antecedent probability of A to B is 2 to 1: the probability of their producing M is as 2 to 3; the product is 4 to 3. In other words the probabilities in favour of A being the cause are as 4 to 3. And so on with any other combination.'

The principle may be applied to distinguish casual coincidences from those that result from law. 'The given fact may have originated either in a casual conjunction of causes, or in a law of nature. The probabilities, therefore, that the

fact originated in these two modes, are as their antecedent probability, multiplied by the probabilities that if they existed they would produce the effect. But the peculiar combination of chances, if it occurred, or the law of nature if real, would *certainly* produce the series of coincidences. The probabilities, therefore, are as the antecedent probabilities of the causes. One of these—the antecedent probability of the combination of mere chances that would produce the given result—is an appreciable quantity, on the principles already laid down. The antecedent probability of the other may be estimated more or less exactly, according to the nature of the case.'

CHAPTER X.

INDUCTION AIDED BY DEDUCTION.

1. It is desirable at every stage to carry out Inductive laws into their Deductive applications. Now, Deductions cannot be made or verified without Observation of facts.

Deduction or Ratiocination, in its purely formal aspect, is given in the Syllogism In its material side, it involves the comparison of facts, and is akin to Induction. We have yet to view it as it plays a part in the Inductive Sciences.

2. The full scope of the Deductive Method comprises three operations.

I. There must be certain pre-established INDUCTIONS.

We must somehow arrive at Inductive Generalizations, and next prove them when arrived at. The Experimental Methods have in view these two ends, and especially the last, namely, Proof. Incidentally, the methods indicate the mode of Discovery, but they have not been expressly aimed with that view. It has been apparent, however, that the collection and study of instances, under the Method of Agreement, must suggest the points of Agreement, when we are ignorant of them, which is to suggest a general law. Our examination of the problem of Crystallization, and the enquiry into the cause of Dew, led first to the discovery, and next to the proof, of generalized coincidences. Still, it was not advisable to carry on a double

illustration, by means of the Experimental Methods, to elucidate at once Discovery and Proof; of the two ends, the logician has most to do with the second; Proof is his main object, for which he can lay down definite laws; Discovery is a valuable end, likewise, but it is not equally amenable to prescribed rules.

In the management of particular instances, with a view to the Discovery of generalities, assistance may be obtained in the three following ways:—

(1) The *number* of instances should be as extensive as possible. In the comparison of a large number the mind will be struck with points of community, from the very fact of the recurrence; as in the examples collected in the research on Dew. Moreover, there will start forth some one that contains the circumstance sought, in startling prominence; these are the glaring or suggestive instances. Such, in the case of Dew, was the example of the warm breath upon a cold iron surface, as a knife blade.

(2) When out of mere number and variety of instances, the identity does not flash upon the mind, the next thing is to *select a few* for careful scrutiny. Each instance should be studied in isolation, should be gone over in every minute point, and examined from every side; the features being exhaustively set down in writing. After a few separate instances have been considered in this thorough way, the resemblances (unless at the time inscrutable for want of other lights) will become apparent to the view. Newton's study of the phenomenon of the coloured rings of the soap-bubble, was an exercise of the severe mental concentration now described.

(3) The general laws of phenomena must be sought in the cases where they are *least complicated* or combined with other laws. This is an obvious precaution conducing to Discovery. The laws of motion are studied in simple cases, such as straight-lined movements, or wheel-movements, under a single impulse. Gravity is best studied in bodies falling perpendicularly, where there is no other force operating. Neither the first law of motion, nor the law of gravity, could have been advantageously generalized, in the flow of rivers, or in the motions of the planets. These complications are not suited for inductive discovery, but for deductive application, as at present contemplated. The first principles of Optics are sought, not in the workings of the eye, nor in complicated lenses, but in the simple mirror for reflexion, and in the plane transparent surface for refraction. So the more transcendental powers of light, in causing mole-

cular change, are not studied on the retina of the eye, but in the easier (although still obscure) cases—chemical action and photography. The osmotic action of cells is illustrated by Graham's experiments on the passage of liquids through porcelain partitions. The capillary circulation of the blood is compared to the flow of liquids in capillary tubes. Salivation and digestion are examined by withdrawing saliva and gastric juice from the animal body, and subjecting different materials to their action apart. The laws of Mind, which are to be carried out deductively in resolving the complicated situations of human beings, as in Society, are to be generalized from observations of the individual man in favourable situations. For the laws of mental growth, we have to begin at infancy; for the germs of moral sentiment, we refer to the uncivilized races.*

3. II. DEDUCTION proper involves two stages of complexity; (1) The simple extension of an inductive law to a new case, and (2) the combination of several laws in a conjoint result, involving processes of Computation.

(1) Simple Deduction is the extending of an inductive generalization to new cases. As in all enlargements of knowledge, so in this, there is both discovery and proof. The cases have first to be suggested to the mind, and next to be rigorously verified by the procedure suited to the case.

Without dwelling upon the means of suggesting new applications of laws, let us consider the mode of proving such applications. This resolves itself into a *question of identity*.

Supposing that the inductive proposition 'all matter gravitates' has been formed upon solids and liquids, shall we apply it to gases? This depends upon whether gases are matter—whether any property of gases is identical with the defining property of matter. Now, the defining property of matter is inertia, and gases are proved to possess this property; whence, the proposition 'matter gravitates' is extended to them. Again, Does Ether (the supposed medium of Light and Heat) also gravitate? As before, we must test its identity with the characteristic property of matter. Now, if, as seems to be implied in the retardation of Encke's comet, the ether is a resisting substance, then it is matter, and accordingly gravitates.

* The Arts of Discovery, brought out by scattered allusions throughout the work, will be systematically given in APPENDIX H.

Questions of identity to establish a minor are necessarily part and parcel of inductive research; but they must not be confounded, as they sometimes are, with the process of inductive generalization to establish a major or a general law. Thus, it is a moot point, whether any, and what alloys are chemical compounds; which must be settled by examining the characteristics of alloys, and comparing them with the essentials or characteristics of chemical combination.

We may instance important researches that have for their end the proof of an identity. Thus, Dr. Andrews instituted a series of experiments to identify Ozone (formed by Electricity) with the atmospheric constituent that decomposes Iodide of Potassium. He selected three peculiarities of ozone;—(1) the power of oxidizing mercury, (2) the destruction of ozone reactions by dry peroxide of manganese, (3) the destruction of its reactions at a high rate of temperature (237° C); and tried the element found in the atmosphere by these tests. It answered to them all. The first, however, (the oxidizing of mercury) is not conclusive, as other bodies, besides ozone, tarnish mercury. The last of the three tests (high temperature), answers to no known substance, except ozone. The three tests conjoined furnish superabundant evidence of the identity of the so-called ozone of the air, with ozone as obtained by electrolysis, and by the electrical machine.

Another remarkable discovery of Identity is seen in Graham's experiments on the relations of Hydrogen to Palladium. There have always been chemical reasons for believing that hydrogen gas is the vapour of a highly volatile metal. Graham has contributed new evidence in favour of the identity. The metal palladium is capable of absorbing eight or nine hundred times its volume of hydrogen gas; and, when so charged, is found to undergo changes in Density, Tenacity, Electrical Conductivity, Magnetism, relations to Heat, and Chemical properties. On investigating these changes, Graham shows that they correspond to the alterations made on one metal when united *in an alloy* with another metal; so that, as far as metallic properties can be shown in such a union, hydrogen is metallic. The metal 'hydrogenium' has a white aspect, is of sp. gr. 2, has a certain amount of tenacity, and is magnetic. The cumulation of proof is all but equivalent to the separate production of the solid metal.

Sir G. C. Lewis confounds the establishment of a minor, as a part of Deduction, with the establishment of an Inductive major by the method of Difference. He considers that the

proof of a burglary in a Court of Law, or the proof that Sir Philip Francis wrote Junius, is an employment of the Experimental or Inductive method of Difference as one of the Inductive methods. In reality, all such cases are the making good of an identity to prove a minor. The kind of Difference employed consists in bringing out successive details or circumstantials, to *exclude* by degrees every person but one; and thereby to complete the identity of that one person with the actor in the given case.

(2) The more difficult employment of Deduction is in the concurrence of different agents to a combined result; as when we deduce the path of a projectile from gravity, the force of projection, and the resistance of the air; or the tides from the united action of the sun and the moon. This is the form of the Deductive Method, whereby we cope with the otherwise intractable situation called Intermixture of Effects.

Physical Astronomy will ever remain the grand exemplar of Deductive Investigation, as the computation of joint causes producing an effect. The causes can be estimated with numerical precision, and their combined operation can be calculated by the higher Mathematics. In other parts of Physics, there are instances of the Deductive Method. The calculations respecting Machinery, Fluid Pressures, Motions of Fluids, Gaseous Pressure and Movements, Sound, Light, Heat, Electricity,—proceed upon inductive laws, often united in their operation, and requiring to be computed in their joint effect.

It has been seen, in the research on Dew, that Dalton's generalization of the laws and constitution of the atmosphere of vapour, deductively applied, made up the wanting link in the experimental investigation.

Equally telling examples of the Deductive Method may be culled from the recent applications of Chemistry to Animal Physiology. The laws of chemical combination enable us to trace the metamorphosis of tissue, by means of the products of waste. The single fact of oxidation is all-pervading in the animal system, and the deductions from it clear up at once many obscurities beyond the reach of experimental elimination. The difficult question of Animal Heat is to a great extent solved already by this deductive application, and its complete solution will probably depend on the same method.

We may quote farther the special applications of Chemistry, under the great law of Persistence, to the phenomenon of muscular power, of which no adequate account could be given by mere observation or experiment. We now know that

muscular expenditure represents a definite combustion of the material of the food, although we do not know the precise links of the transmutation.

When purely Inductive or Experimental proofs are supported by *reasons*, or by a consideration of the *nature of the case*, the meaning is that Deduction is brought to the aid of Induction. The conclusion respecting the N. E. wind was confirmed by the general operation of atmospheric impurities. The result gained from the comparison of instances of Crystallization, is in accordance with the theoretical views of the two opposing molecular forces — attraction and repulsion. The experimental facts as to the exhaustion of the mind along with the body, are supported by what we know of the brain as the organ of the mind. Our inductions respecting despotic governments are aided by deductions from the laws of human nature.

The applications to the Human Mind, to Character, and to Society, will be more fully exemplified afterwards, in the special chapters on the Methods of these Sciences.

4. III. The Deductive process is completed by VERIFICATION.

This applies more particularly to the Computation of combined causes.

The way to verify the deductive extension of a single law to a new case, is actual observation of that case. We apply deductively the law of gravity to air, and verify the deduction by observing whether the air has weight. As, however, we may dispense with deduction when we have actual observation, such an instance does not show the power of the Deductive Method. The thing meant is, that after verifying a deduction by one or more instances, we shall be able to apply it to other instances without farther verification; these last instances depending for their proof solely on the deductive process.

When an effect is the result of several conspiring causes, we may deduce it from a computation of the causes; as, for example, the lunar and planetary perturbations. To show that we have taken account of all the causes, that we have obtained a proper estimate of each, and that we have correctly computed their conjoined action, we must compare the deduced effects with the observed effects in a variety of instances. If the two precisely tally, the deductive machinery is verified; if not, not. A want of accordance points to a defect in one or other of the circumstances quoted:—the causes or agents are

not fully taken account of; their exact amount is not precisely obtained; or the calculation of their united action is not perfect. Sometimes, the first point is defective, there being a residual agent. In other cases, we know the cause but not its exact numerical amount; thus, in Astronomy, we need to know the relative masses of the sun, moon, and planets, together with their mutual distances. Finally, it may happen that the calculations are impracticable.

In Astronomy, where Deduction has gained its greatest triumphs, verification has also been most thoroughly worked. Upwards of fifty Observatories are incessantly engaged in watching celestial phenomena; the observations have been the means of perfecting the deductive operation, and making good all its shortcomings.

The deductive theory of projectiles combined gravity, projectile force, and the air's resistance; the experiments on gunnery are the verification.

The laws of the strength of materials are deduced from geometrical and mechanical laws, involving the size, shape, and position of beams, &c.; but however certain the principles may appear, they cannot dispense with actual trials.

We have supposed the verifying tests to consist of detached observations; they may be furnished by groups of observations, summed up into what are termed Empirical Laws. Such was the verification of Newton's planetary theory (founded on gravity) by Kepler's Laws. So, any theory or generalization of the operation of refracting surfaces on light, must be in consistency with Snell's law of the proportion of the sines of incidence and refraction.

The formulæ of fluid motions are of themselves insufficient to predict the facts; experiments on the flow of rivers must be conjoined in a matter of so great complicacy.

Newton calculated deductively the velocity of sound, and, on comparing it with the observed velocity, found a difference of nearly twenty per cent. It is only of late years, that the discrepancy has been got over, by a more complete view of the forces developed in the act of propagation. In such a delicate question, one verifying instance is too little. Newton himself squared the results by arbitrary assumptions (as the thickness of the air particles), which would have required for their confirmation an independent class of facts.

Very confident predictions have been made to the intent that the Sun is cooling down in consequence of his enormous radiation; and that the earth's rotation must ultimately decay,

through the friction of the Tides. The data and the calculations seem very secure in both instances; yet, in order that the deductions may be fully established, we need evidence of an actual change, in past time, as regards both these momentous facts.

Combined Induction and Deduction expresses the full force of scientific method for resolving the greatest complications. Induction alone, and Deduction alone, are equally incompetent to the great problems even of the Inorganic world; still more so with Life, Mind, and Society. Induction, exclusively relied on, is called 'empiricism;' Deduction, without an adequate basis and an adequate check in the Inductive Methods, expresses the bad sense of 'theoretical.'

The two following chapters will continue the exemplification of the Deductive Method, of which they merely vary the aspect.

CHAPTER XI.

SECONDARY LAWS—EMPIRICAL AND DERIVATIVE.

1. The importance of Secondary (as opposed to Ultimate) Laws, grows out of their close adaptation to concrete realities.

Speculation delights to attain ultimate generalities, which give the key to a vast department of nature; as Gravity, Conservation, and Relativity. These are highly satisfactory to the mind in its craving after unity, simplicity, 'the one in the many.' A far more important use of these supreme generalities is to perfect the statement of the Secondary Laws, which are the more immediate guides of conduct, and the expression of the phenomena in their actual or concrete embodiment. The generalization of gravity did not supersede Kepler's Laws of the Planetary Motions. So long as the concrete fact of planetary motion has an interest for us, so long are we concerned with the secondary laws representing that fact. The use of the higher laws of Newton is to render these indispensable secondary laws more precise.

The secondary laws are the 'media axiomata' of Bacon. They were viewed by him (too exclusively) as the steps for ascending to the supreme laws. Equally essential is the

descending movement from the higher to the middle generalities. No branch of knowledge is complete until it has assembled all the secondary laws that express the more usual configurations of actual phenomena, and until these secondary laws have attained all the precision that induction and deduction can give them.

We formerly had occasion to remark (p. 79), with reference to Propositions, that, like the notion, they vary in regard to the reciprocal properties—Extension and Comprehension. As we increase the extension, we lose comprehension, and conversely. Now, of the two attributes, the one most important for us practically is Comprehension. We have to deal with small classes, and with individuals, and our interest lies in knowing the whole of the specialities attaching to these. An English statesman needs to know the peculiarities of Englishmen. A physician has to deal with the diseases special to humanity, and still more those special to his own sphere; while even this degree of generality, is but to prepare him for mastering individual cases.

Hence, the *narrowing* of a proposition, which may seem a defect to the theorizing or speculative intellect, is the highest merit in applications to practice: provided always that the limitation of extent is accompanied with a corresponding increase in amount of predication, that is, in meaning, connotation, or intent. The full enumeration of the properties special to iron, as it is found in a certain district, is essential to the working of that particular ore; the account of the properties common to all metals would be valuable merely as contributing a quota to the highly specialized and exhaustive knowledge relative to the particular substance.

It was a frequent remark of Aristotle that the finishing stroke of knowledge is the *tact* that modifies all general propositions according to the individual case. This of course is in the more purely practical point of view.

The secondary laws are either EMPIRICAL or DERIVATIVE.

2. An EMPIRICAL LAW is a uniformity supposed to be secondary, that is, resolvable into some more general uniformities, but not yet resolved.

That quinine cures a fit of ague is an Empirical Law. It is a uniformity established by experience; it is, however, a secondary uniformity; we have reason to believe that it is

capable of being resolved into higher uniformities. The present inability to resolve it is a disadvantage, not merely in a theoretical or speculative point of view, but as regards the application of the law in practice.

3. When what was an Empirical Law has been resolved into more general uniformities, or into highest laws, it is termed a DERIVATIVE LAW.

The occurrence of snow on high mountains was at one time an empirical uniformity. It was established as an induction from experience, but was not susceptible of being referred to any higher generalizations. We can now resolve it into the laws connected with radiant heat passing through the atmosphere. These may not themselves be the highest attainable generalities; still they are much more general than the induction connecting snow with height.

The converting of an Empirical Law into a Derivative Law is a step gained both in scientific explanation, and in practical facilities. The defects inherent in an Empirical Law do not inhere to the same degree in a Derivative Law.

4. Empirical Laws are of various kinds. Their characters are judged from their appearance after being resolved, that is, made derivative.

I. Many are obviously made up of the combination of higher uniformities under definite arrangements or collocations.

We see this class largely exemplified in the explained or derived laws. The law of a projectile, Kepler's laws, the tides, the laws of wind and rain, the laws of geological action (igneous and sedimentary), combustion, the nourishment of living bodies—being formerly empirical laws, and now derived—we can, from them, presume the character of those that are still empirical.

These combinations have been already discussed under the Deductive Method. They suppose certain ultimate laws, concurring in their operation, and also a certain definite arrangement and amount of the concrete agencies or forces that the laws refer to.

5. II. Some secondary laws take the form of laws of succession between effects and *remote* causes; they still, however, possess the character last named.

When a sudden shower disperses a crowd, the shower is a very remote cause of the effect; a number of intermediate links of causation are assignable. The taking of food is removed by a good many stages from the renewal of the muscular strength. The sowing of a seed is followed at a long interval with the maturing of an oak.

This is merely a superficial variety of the first case—combination of agents, in definite collocation. Each one of the links is a distinct law of causation or coincidence, requiring to be embodied in a definite collocation; and the combination of the whole, in a suitable arrangement, is necessary to the result.

6. III. Some are laws of Co-existence or of Succession between effects of the same cause.

Such are the phases of the Tides, the flow of the Seasons, Day and Night. Here also there is the same constant circumstance—a conjunction of agents and collocations. In every case of a secondary law, there is, from the nature of the case, more than one power at work. Only ultimate laws express agents in isolation, purity, or abstractness.

In any complicated structure, a new agent produces a variety of changes. The taking of food leads to concurring alterations in almost every organ in the body. Every disease has concurring symptoms. A country engaging in war has its economy simultaneously disturbed in many different ways; hence there are numerous empirical statements applicable to the condition of war, which are co-effects of the one general situation.

7. The aggregation of properties in a natural kind—a mineral, plant, or animal—has something in common with Empirical Laws.

As there may be uniformities of co-existence, not resolvable into cause and effect, such uniformities stand solely on their own inductive evidence, like empirical laws. They are proved by the method of Agreement alone, and the proof extends no farther than the cases observed.

8. The criteria of an Empirical Law are principally these :—

If a uniformity is established only by Agreement, it is not shewn to be a law of causation; and (if not an ultimate law of co-existence) it is an empirical law.

Agreement does not single out a cause when there is plurality. It is at fault, besides, in discriminating cause and effect from effects of the same cause. Moreover, unless the variation of the circumstances has been thorough and complete, there is an uncertainty even in cases where there is but a single cause, and where the antecedents contain that cause.

The Method of Difference does not at once lead to ultimate laws. The swallowing of alcohol is followed by a certain sensation; this is proved by the Method of Difference to be cause and effect, yet it is not an ultimate sequence; it is an empirical uniformity.

9. The other criteria arise out of the characters already mentioned.

Thus, when phenomena are obviously complicated, and when there are intermediate links of operation, the laws of such phenomena are not ultimate but secondary; they are empirical, or, if resolved, derivative.

The law that connects the fall of the barometer with wind or rain is plainly empirical. We can see that many different agencies enter into the sequence; and, also, that there are many intermediate steps between the antecedent and the consequent.

We presume the action of a drug to be an empirical law, because we know, from the complication of the human body and the plurality of attributes of natural kinds, that there must be many concurring processes, each one governed by its own law or laws of causation.

LIMITED APPLICATION OF DERIVATIVE AND EMPIRICAL LAWS.

10. A Derivative Law, and still more an Empirical Law, must not be extended beyond narrow limits of Time, Place, and Circumstance.

It being supposed that such laws are established by all the evidence that the case admits of, still they are applicable only a certain way beyond the narrow sphere where they have been observed to operate.

The reasons are those already stated under the Deductive Method. A uniformity depending on several higher uniformities, and on a definite collocation of agents, that is, on certain special co-efficients, must fail, first, if any of the concurring uniformities be counteracted, and secondly, if the proper adjustment of the agencies is departed from. The elliptic

motion of the planets would be defeated, if some great disturbing body were sufficiently near to counteract solar attraction, or if the tangential force were made different from what it is. Hence we cannot extend the law of the ellipse to every body that may now or at any future time revolve about the sun.

This limit to the extension of secondary laws—whether Empirical or Derivative—is the all-important fact respecting them, in the logical point of view. A large number of prevailing errors might be described as the undue extension of Empirical Laws. We shall present a few examples of secondary laws, calling attention to the difference of our position in regard to them, according as they are Empirical or Derivative.

The rise of water in pumps was an empirical law, previous to the discovery of the pressure of the atmosphere. The application of the Method of Agreement in different countries, and with pumps of different bore, proved that no pumps could draw water beyond about 33 feet. The law could be relied on within the wide limits of place and circumstance where it had been tried. It could not have been extended to other planets; but it might be extended, with apparent safety to any part of the earth.

Since the law became derivative, the limits of its operation are precisely defined; we can tell exactly where it would have failed. We know that on the tops of high mountains the maximum height would have been much below 33 feet; that the exact height would not be the same at all times; that other liquids, as alcohol, sulphuric acid, solutions of salts, mercury, vary in the height attained. Now, probably none of all these limitations had been actually discovered in the empirical stage; they *might* have been obtained by sufficiently wide and careful experiments; the derivation superseded the laborious task, which was probably beyond the competence of an unscientific age.

It is an empirical law that the temperature of the earth increases, as we descend, at a nearly uniform rate of 1° of Fahrenheit to 50 feet of descent. This law has been verified by observations down to almost a mile. We might extend the law inferentially to the adjacent depths, as far perhaps as several miles; but we are not at liberty to extend it to the centre of the globe. We do not know that the requisite collocations extend so far.

Yet this law is not wholly empirical. It is a derivative uniformity. It is connected with the known facts—that the

earth has a high temperature in the interior, and is cooled at the surface by radiation in space. Knowing these, we are yet unable to deduce the law of decrease from the higher laws concerned, because we are ignorant of the degree of central heat, and imperfectly acquainted with the laws of its conduction through the unknown materials of the globe. We understand the general situation, but do not possess the numerical and other data requisite for computing the effects.

That air-breathing animals are hot-blooded, is a law formerly empirical, now derivative. It comes under the general law of the dependence of temperature on the oxygenation of the blood, and may be extended widely on the faith of that great generality.

The Law of Continuity—'Natura non agit per saltum'—is an Empirical Law. In the continuity of Vegetable and Animal Life, there would be, under the Doctrine of Development, a reason for the fact, and it would be in that case Derivative. Also, in the transition from one state of matter to another,—as in melting, boiling, and their opposites—there must be a certain amount of continuity owing to the greatness of the transition. But except where there is some presumption of this nature, the extension of the law is wholly unsafe; we are not to expect, for example, that the simple bodies of nature should be arranged in series with continuous or shading properties. We find the greatest gaps in almost all the properties of the elementary bodies.

In medical science, there is hardly such a thing as a single effect produced by a simple cause. What is worse, there are scarcely any great inductive generalities relating to the cure of disease, except through hygienic or constitutional treatment. Thus the use of drugs is almost exclusively empirical.

The limitation in this case operates variously. It forbids our inferring that two medicines of close kindred will have the same effect; thus bark and quinine are not interchangeable, although the one is the crude form and the other the essential extract. It also forbids our extending a mode of treatment to a closely allied ailment, as in reasoning from one species of fever to another. Lastly, it forbids the application of the same treatment to the same disease, in different persons.

Hence, medicine is of all sciences the one most completely tentative. Experience gives a probability to begin with; but until the effect is tried in the new case, we cannot, as a general rule, rely on it.

Until the day arrives when the operation of medicines is made derivative, the only progress possible is to obtain through multiplied experience, a more exact statement of the conditions attending on the successful application of certain modes of treatment; as for example, the constitutional or other circumstances in the patient favourable or unfavourable to special drugs.

The treatment of tape worm by male fern is of old date in medicine. In the early period, the failures were frequent; at present, the oil of the fern is extracted and given instead of the root, with an almost uniform success. This empirical uniformity is to a certain extent derived or explained; the substance is a poison to the parasite. After such an explanation, there is afforded a clue to other remedies for the disease; previous to the explanation, the uniformity was confined to the one remedy.

As an empirical law in Medicine, we may instance Bright's discovery of the connexion between albuminous urine, and degeneration of the kidney. The law is as yet unresolved into any higher law of structure and function; the kidney degeneration is not associated with degeneration in any other tissues of the body; and no account is given of the temporary production of albumen without the permanent disease.

It is an empirical law that about 250 persons in a year commit suicide in London. This law may be extended a little way into the future, but it may not be extended into a remote time, when moral habits may be different, nor to other cities and populations.

The Statistics of Mortality show a remarkable coincidence between the rate of mortality and the density of the population. A high degree of longevity is found in thinly peopled districts, notwithstanding even the poverty that sometimes occurs in sterile tracts; and mortality reaches its maximum in the most crowded parts of cities. If we knew nothing of the causes of this uniformity, if it were as empirical as the medicinal action of mercury on the system, we could not extend the law into other countries and other circumstances of the population. But it is a derivative law, and knowing what agents the effect depends on, and what circumstances would defeat their operation, we apply it without scruple to every portion of the human race. We should, however, refrain from applying it to animals very differently constituted from man as to the necessities of breathing pure air. All animals require oxygen, but some need it in smaller quantity, and are indif-

ferent to impure gases; while warmth and the opportunities of better food might more than compensate for the close atmosphere of a confined habitation.

In regard to the Human Mind and character, we have uniformities that cannot be extended to the race generally. Thus, the universality of sympathy or fellow-feeling is liable to exceptions. Mr. Samuel Bailey, after quoting, from a traveller in Burmah, the incident of a drowning man being beheld by a crowd as an amusing spectacle, and being allowed to sink without an attempt at succour, makes the following remarks:—

'Incidents of this kind (and the example might be easily parallelled from other nations) serve to show that when we ascribe certain sentiments to human nature or to men universally on given occasions, because they exist amongst ourselves on those occasions, it is by no means a safe inference; we cannot safely ascribe them except to men under analogous circumstances of knowledge and civilization.

'We may attribute with confidence to most men and to most races of men, the rudimentary feelings which I have shown to originate and to constitute moral sentiment; and some of them with equal confidence to all men: namely, sensibility to corporeal pleasure and pain; liking the causes of one and disliking the causes of the other; the propensity to reciprocate both good and evil; the expectation of the same reciprocation; and more or less sympathy with other sensitive beings; but the direction and intensity of these emotions respectively it is often difficult and even impossible to assign: there are so many causes at work to counteract, or modify, or suppress such of these common susceptibilities as can be counteracted, or modified, or suppressed—to call them forth or to keep them in, that, unfurnished with precise knowledge of national and social circumstances, we cannot predict with confidence how they will manifest themselves on particular occasions. Without specific information of this kind we cannot safely pronounce that the people of rude or distant and imperfectly explored countries would, under given circumstances, share in those affections and moral sentiments which it seems contrary to our own very nature, under such circumstances, not to have.'

That 'the mind of man is by nature conciliated and adapted to his condition' was formerly an empirical law. We may now consider it as a deduction or derivation from the law of Universal Relativity. The principle has been greatly abused. It has been loosely extended far beyond the limits where it is

observed to hold true ; indeed those limits were never correctly marked in its empirical state. As a derivative uniformity, we may assign its limits with tolerable precision.

The laws of Political Society are all secondary laws, either empirical or derivative. Hence the necessity for limiting their application. The politician is, like the ancient sailors, obliged to sail close by the shore, rarely venturing out of sight of land.

We are not at liberty to transfer to our own time the maxims suitable to the ancient world, supposing even that the ancients really attained any political rules highly salutary in their own case.

'The distinction between ancient and modern history,' says Mommsen, 'is no mere chronological convenience. Modern History is the entry on a new cycle of culture, connected at several epochs of its development with the perishing or perished civilization of the Mediterranean States, but destined to traverse an orbit of its own.' It would be a vicious extension of secondary laws, to predict the extinction of modern nations, because the great ancient empires are perished.

We cannot transfer at once the practice of one nation to another nation. Hardly any political device has been so much copied as the British constitution Yet, its advantages being not purely empirical, but to a certain extent derivative, it may be extended to adjacent cases with some confidence.

It is suitable to the complicacy of the political structure to make changes in the direction of existing institutions, and to confide in them only when introducing a state of things nearly adjacent to the present. After seeing the working of a ten-pound franchise in this country, the inference was fair that the lowering to eight, seven, or six pounds could not depart very far from actual experience.

The use of precedents in Law and in Politics exemplifies the rule of limitation. Bacon, remarking on legal precedents, lays it down that *the more recent* are the safer, although, on the other hand, they have a less weight of authority. 'A precedent is at its maximum of proving force when it is sufficiently near our own time to ensure similarity of circumstances, and sufficiently distant to ensure the consolidation of practice, and the experimental exhibition of the practical result.' (G. C. Lewis).

11. The rule may be farther illustrated under the second form of the Secondary Laws—Uniformities of remote connexion between cause and effect.

Of these, the most prominent examples are the results of slow processes in the arts, protracted treatment in disease, the growth of plants, the development of animals, the formation of the human character. That all empiricisms of this class must be precarious and liable to frequent defeat is apparent. Even when derivative to the full extent, they are rendered uncertain by the number and complication of the agencies.

12. Lastly, with reference to Uniformities suspected or known to be effects of a common cause.

The principle of limitation is still the same.

As an example, the case is put—what reliance are we to place on the sun's rising to-morrow?

Suppose, in the first place, that this were an *empirical* generality, we being ignorant of its derivation. Suppose, also, that we have authentic evidence that the sun has risen daily for the last five thousand years. How far into the future are we at liberty to extend the law; to what limits of time should we confine it? The answer is, we may count the continuance in the future, *on the same scale* as the continuance in the past; we may fairly assume a period counted by thousands of years; we may be tolerably certain for one thousand years, and have a considerable probability, for three, four, or five thousand; but we should not be safe in extending the scale to tens of thousands, still less to hundreds of thousands. For anything we should know, a catastrophe may be preparing that will speedily interfere with the regularity of day and night; still, long continuance in the past reduces, without annihilating the chances.

Let us next look at the case as a *derivative* uniformity. We know that the phenomenon will continue so long as these circumstances are conjoined, namely, (1) the luminosity of the sun, (2) the earth's being within a proper distance of the sun, (3) the earth's rotation, and (4) the negative condition of the absence of any intervening opaque body to act as a screen. Now, we know from past experience that all these conditions are likely to be perpetuated for a period of time, to be estimated by not less than hundreds of thousands of years. The sun may be cooling, but the rate, judging from the past, is extremely slow; the earth's rotation is believed to be subject to decay, but the rate of decay is infinitesmally little; the removal of the earth out of the solar influence is in opposition to our very best guarantees; and the permanent intervention of an eclipsing body is the most unlikely incident of all. Thus,

then, while, as an empirical law, we cannot well extend the rising of the sun (or day and night as we now have it) beyond thousands of years at most, we may extend it, as a derivative law, to hundreds of thousands, if not to millions.

EVIDENCE OF THE LAW OF CAUSATION.

13. It may be shown that the Law of Causation, the indispensable ground work of all Induction, itself reposes on the highest evidence suitable to the case—uncontradicted Agreement through all nature.

We have hitherto taken for granted that sufficient evidence, of the only kind suited to the case, has been obtained in favour of the law of Universal Causation, on which law have been grounded all the processes of experimental elimination. A summary of this evidence will farther illustrate the logical processes detailed in the foregoing chapters.

The uniformity of successions was first observed in easy instances, such as the more obvious mechanical effects. A body at rest was observed never to move from its place without the application of some force to move it; a body in motion was observed not to stop abruptly without interference and obstruction. The fact of the descent of unsupported bodies is invariable. So light and heat display obvious regularities that could be counted on. Even in the instability of the winds there would be discovered circumstances of constancy. The most complicated of all things, living bodies, were seen to have numerous points of striking uniformity.

That change of every kind whatsoever follows on a definite prior change, could not be affirmed in early times, except by the mere instinct of generalization, which is no proof. Hence in ancient philosophy, there were alternative suppositions. Aristotle allowed an element of Chance, along with the reign of Law.

Modern science has extended the search into natural sequences, collecting new examples of uniformity, and removing exceptions and apparent contradictions. Investigations have been pushed into every department of nature; and had there been any decisive instances where change grew out of nothing, or where the same agent, in the same circumstances, was not followed by the same effect, such instances must have been brought to light.

14. In the form of Persistence of Energy, under definite

laws of Collocation, the Law of Cause and Effect has been subjected to the most delicate experimental tests.

By irrefragable observations it was shown that Matter is indestructible, which is one element of nature's constancy. Farther observations have proved the numerical Persistence of Force throughout all its transformations, and also the uniformity of the collocations or arrangements for transferring it.

The first contribution to this result was the proof of the Laws of Motion, as respects both the continuance of motion once begun, and the conservation of the total moving force in case of transfer by impact. These mechanical verities make up one department of uniform cause and effect. Next came the proof of the equivalence of mechanical force and heat—the constancy of the amount of one produced from a definite amount of the other. Joule's mechanical equivalent of Heat testifies to nature's constancy in a very wide department. Following on this is the numerical estimate of the heat of Chemical combinations, also admitting of numerical statement, from which there is no deviation; a third great department of constancy is thereby established.

If numerical equivalence has not been arrived at in Nerve Force, and in Light, the subtleties of the phenomena are sufficient to account for the deficiency. We have reasonable ground to presume that, according as these phenomena are fully understood, they will show the same constancy as all the rest; the burden of proof lies upon any one maintaining the contrary.

The only exception usually claimed to the Law of Causation is the alleged Freedom of the Will. But whatever be the mode of dealing with this long-standing enigma, there is a statistical testimony in favour of the constancy of human motives. The actions of men have a degree of regularity compatible only with uniform causation.

Mr. Mansel has characterised as a 'paralogism' the doctrine that 'the ground of all Induction is itself an Induction.' He might have called it a *paradox* or an *epigram*, an apparent contradiction needing to be resolved: it is not a paralogism unless it can be made out a self-contradiction.

If the account given above of the methods of Proof and Elimination is sufficiently intelligible and conclusive, nothing farther is necessary to resolve the paradox There is one fundamental mode of Proof—Agreement through all nature—by which all ultimate laws are established, including Causation.

There are several derivative, deductive, or dependent methods of Proof, the special Methods of Elimination—Agreement (according to Mill's Canon), Difference, and Variations; these are called by courtesy Inductive Methods; they are more properly Deductive Methods, available in Inductive investigations. The special form of Agreement described in the canon is not quite the same as the fundamental method of Agreement, on which alone repose all the ultimate generalizations. That canon, as supposing Causation, would be inapplicable to the proof of Causation. The method of Agreement that proves Causation is not a method of elimination. It does not proceed by varying the circumstances, and disproving successive antecedents; it can only find A followed by *a*, wherever the two occur. Until the law is first proved, we cannot establish A as the cause of *a*, by omitting successively B, C, D, and all other accompanying circumstances, leaving nothing constantly joined save A and *a*; even if this were done, there must still be a search through all nature for A followed by *a*, when the question of causation itself is at issue. Hence Agreement for establishing an ultimate law is not the same as the Method of Agreement, in Mill's canon, for establishing cases of causation, *after* the general law is sufficiently guaranteed.

There is a certain propriety in comparing the establishment of the Law of Causation (or any other ultimate law), with the proof of an Empirical Uniformity, which has nothing but detailed Agreement to found upon. True, an Empirical Uniformity is to be applied only a little way beyond the limits of time, place, and circumstances But, now, as Mr. Mill remarks, 'if we suppose the subject matter of any generalization to be so widely diffused, that there is no time, no place, and no combination of circumstances, but must afford an example either of its truth or its falsity, and if it be never found otherwise than true, its truth cannot depend on any collocations unless such as exist at all times and places; nor can it be frustrated by any counteracting agencies, unless by such as never actually occur. It is, therefore, an empirical law, co-extensive with all human experience; at which point the distinction between empirical laws and laws of nature vanishes, and the proposition takes its place among the most firmly established, as well as largest truths accessible to science.'

CHAPTER XII.

EXPLANATION OF NATURE.

1. The laws arrived at by Induction and Deduction are the proper EXPLANATION of natural phenomena.

Explanation has various meanings. These all agree in affording us a certain satisfaction or relief when oppressed with the difficulty, obscurity, perplexity, contradiction, mystery, of natural facts. But the human mind has at different times been satisfied in different ways; and individuals still vary as to the kind of explanation that satisfies them.

When all Nature was peopled with deities, and the various phenomena partitioned among them, a sufficient explanation of anything was that a certain god or goddess willed it. The intervention of Neptune was a satisfying account of why a storm arose. The wrath of Apollo was the explanation of the plague that broke out among the Greeks at the siege of Troy.*

There is a special and every-day form of explanation that consists in assigning the agency in a particular occurrence; as when we ask—what stops the way? who wrote Junius? who discovered gunpowder? These questions belong to our practical wants and urgencies, but the answer does not involve the process of scientific explanation. If, however, we proceed from the 'who' or 'what' to the '*why*:'—why does A's carriage stop the way? why did the author of Junius write so bitterly?—there is an opening for the higher scientific process.

2. The basis of all scientific explanation consists in assimilating a fact to some other fact or facts. It is identical with the *generalizing* process, that is, with Induction and Deduction.

Our only progress from the obscure to the plain, from the mysterious to the intelligible, is to find out *resemblances* among facts, to make different phenomena, as it were, fraternize. We cannot pass out of the phenomena themselves. We can explain a motion by comparing it with some other motion, a

* See GROTE'S Plato (*Phædon*) for the views of the ancient philosophers with regard to Explanation, or the Idea of Cause.

pleasure by reference to some other pleasure. We do not change the groundwork of our conception of things, we merely assimilate, classify, generalize, concentrate, or reduce to unity, a variety of seemingly different things.

The phenomenon of combustion was considered to have been explained when Priestley showed it to be the combination of oxygen with carbon or other substance; in short, he assimilated the fact to cases of oxidation, as the formation of the red precipitate of mercury, the rusting of iron, &c. Lightning was explained by Franklin's assimilating it with electricity. The polarity of the needle was explained by assimilating the entire globe to a magnet or loadstone.

Explanation thus steadily proceeds side by side with assimilation, generalization. Combustion was explained by oxidation; oxidation is explained by the higher generality—chemical combination; chemical combination is swallowed up in the Conservation of Energy.

3. Mr. Mill distinguishes three forms of the explanation of facts and laws.

I. Explaining a joint effect, by assigning the laws of the separate causes, as in the ordinary Deductive operation.

The Deduction of a complex effect, by computing the sum of the separate elements, is also the explanation of that effect. By combining gravity with projectile impulse, we explain the motions of the planets. This deduction once verified, is offered as the explanation of the planetary motions. In other words, the showing that these motions are made up of the two causes—gravity and tangential force—is the explaining of their motions.

In such cases, the explanation points out the simple causes concurring, in the shape of forces or agencies, and also indicates their amount and their due concurrence. Jupiter's orbit depends on the mass of the sun, on the tangential force of the planet, and on its mean distance from the sun. These are, in the language of Astronomy, the *coefficients*, which must be given in order to our assigning the result of the operation of the *laws*. A mere law, such as the law of gravity, is not an explanation until it is clothed in the concrete statement of two or more gravitating masses, with a given amount and a given distance from each other. These numerical statements, the coefficients of Astronomy, are also said to determine the *collocations* of the agents concerned.

To explain the rise of a balloon, is to give the laws of gravity, of buoyancy, and of gaseous elasticity, and to state the exact weight and elasticity of our atmosphere, and the specific gravity of the mass of the balloon.

To explain genius is to refer it to general laws of the mind, or to certain elementary powers—intellectual and emotional—whose higher or lower degrees and modes of combination produce the kind of intellectual superiority so named.

To explain the rise of free governments is to state the general principles of human action, and the definite collocation of circumstances calculated to produce the effect.

The separate laws are obviously *more general* than the laws of the conjoint effect. Gravity has a much wider sweep than planetary motions; the law of the perseverance of moving bodies in a straight line is far more comprehensive than tangential impulse.

§ 4. II. Explanation may assume the form of discovering an *intermediate link*, or links, between an antecedent and a consequent.

What seems at first sight the direct or immediate cause of a phenomenon may, by the progress of assimilation, turn out the remote antecedent. The drawing the trigger of a musket is followed by the propulsion of a ball The *why* of this phenomenon is given by disclosing a series of intermediate sequences, each of which is assimilated with some known sequence. The trigger by concussion evolves heat; the heat ignites the gunpowder; the gunpowder is a mass adapted for very rapid combustion; the combustion evolve gases which, being confined in a small space, have a very high expansive force; the expansive force propels the ball.

Again, the contact of sugar with the tongue is the precursor of a feeling of the mind, the sensation called sweetness. The explanation, so far as hitherto attained, supplies the following series of closer links. The sugar is absorbed by the mucus membrane of the tongue, and comes in contact with the filaments of the gustatory nerve; there ensues a chemical or some other molecular action on the nerve. This action is of a kind that can be propagated along the course of the nerve to the nerve centres, or the brain; whence are diffused a multitude of nervous currents ending in muscular movements. To the cerebral agitation attaches the mental state called the sensation of sweetness.

The unexplained phenomena connected with the Law of Conservation refer to the intermediate links, or transitions, in the interchange of the mechanical and the molecular forces, and of one molecular force with another. The *molecular processes* in the conversion of mechanical energy into heat, heat into electricity, chemical force into muscular power and nervous power,—are not accounted for: and we see only a beginning and an end where we have reason to believe that there must be various intermediate stages, each susceptible of being assigned and brought under some general law of causation.

The intermediate links, or sequences, are each one *more general* than the combined sequence. Take the case of a sweet taste. The absorptive power of the animal membranes for various substances (the crystalloids of Graham) is a general law, of which the action in tasting is merely one example or application. The molecular disturbance from the contact of nerve and sugar is but a case of chemical or molecular affinity. The current action of the nerve force is a limited instance of current actions; the electrical forces exhibit other cases, the whole being comprehensible under some higher law. Finally, the link that relates the physical actions of the brain with the mental effect belongs to some wider statement that relates mental states generally to their physical concomitants.

As observed, in the previous chapter, it is incident to such many-linked sequences, to be more frequently frustrated than the simpler sequences that make them. A circumstance counteracting any one of the closer links counteracts the whole phenomenon. If the lock of the musket makes an insufficient concussion of the explosive substance; if the gunpowder is rendered incombustible by damp; if the expanding gases burst the piece :—in any one of these contingencies, the ball is not propelled.

5. III. The third mode of Explanation is termed the *Subsumption* of one law into another; or the gathering up of several laws in one more general and all-comprehending law.

This represents the upward march of generalization, pure and simple. We have attained a certain number of inferior generalities, by assimilating individual cases in ordinary induction. We have assimilated the kindling of fires for heat and for light and for the disintegration of compounds, under one head, called combustion; we have assimilated the tarnish-

ing and corrosion of metallic surfaces under another head; we subsume both under the higher law of oxidation, which both exemplify. We have also assimilated the action of acids upon alkalies under a general head: we find that this case can fraternize with the foregoing and with many other phenomena, under a still higher, or more general aspect, signified by *chemical combination.*

So, again, terrestrial gravity and celestial attraction, each the result of separate assimilations, being found to agree, are subsumed into the illustrious unity of Universal Gravitation.

Magnetism, Common Electricity, Voltaic Electricity, Electro-Magnetism, &c., are all strung upon the common thread of Electrical Polarity.

Capillary attraction, solution, alloys (not chemical), cements, &c., are subsumed under the general law of molecular attraction (not chemical) between different substances, named heterogeneous or alien attraction.

Numerous laws of smaller compass are subsumed under Relativity. The pleasures of variety and novelty, the necessity of contrast in works of art, antithesis in rhetoric, the statement of the obverse or counter proposition in science,—are minor laws generalized, but not superseded, by the higher law.

When minor laws are thus merged in a greater law, the mind feels a peculiar and genuine satisfaction—the satisfaction of having burst a boundary to expatiate over a wider field. We rise from a statement bearing upon a small group of facts to a statement comprehending a much larger group; from a ten-fold condensation, we reach a thousand-fold condensation. The intellect, oppressed with the variety and multiplicity of facts, is joyfully relieved by the simplification and the unity of a great principle.

The charm of resolving many facts into one fact was acutely felt by the speculative minds of antiquity. It took a powerful hold of the earliest Greek philosophers; and made them almost unanimous in imagining that all phenomena whatsoever are at bottom one, or are susceptible of being represented in some single expression, being merely the many-sidedness of some single central power, substance, agent, or cause. Such unity was, according to Thales, Water; according to Anaximander, an Indeterminate Substance; according to Anaximenes, Air; according to Pythagoras, Number.

LIMITS OF EXPLANATION.

6. Scientific explanation and inductive generalization being the same thing, the *limits* of Explanation are the limits of Induction.

Wherever Induction (extended by Deduction) can go, there legitimate scientific Explanation can go, they being the same process differently named.

7. The limits to inductive generalization are the limits to the agreement or community of facts.

Induction supposes similarity among phenomena, and when such similarity is discovered, it reduces the phenomena under a common statement. The similarity of terrestrial gravity to celestial attraction enables the two to be expressed as one phenomenon. The similarity between capillary attraction, solution, the operation of cements, &c., leads to their being regarded not as a plurality, but as a unity, a single causative link, the operation of a single agency.

So remarkable have been the achievements of modern times, in the direction of lofty generalities, that some countenance seems to be lent to the ancient dream of attaining an ultimate centralized unity in the midst of the seeming boundless diversity of nature.

It depends purely on actual investigation, how far all phenomena are resolvable into one or into several ultimate laws; whether inductive finality leaves us with one principle, with two, or with twenty principles.

Thus, if it be asked whether we can merge gravity itself in some still higher law, the answer must depend upon the facts. Are there any other forces, at present held distinct from gravity, that we may hope to make fraternize with it, so as to join in constituting a higher unity? Gravity is an attractive force; and another great attractive force is *cohesion*, or the force that binds together the atoms of solid matter. Might we then join these two in a still higher unity, expressed under a more comprehensive law? Certainly we might, but not to any advantage. The two kinds of force agree in the one point—attraction, but they agree in no other; indeed, in the manner of the attraction they differ widely; so widely that we should have to state totally distinct laws for each. Gravity is common to all matter, and equal in amount in equal masses of matter whatever be the kind; it follows the law of the

diffusion of space from a point (the inverse square of the distance); it extends to distances unlimited; it is indestructible and invariable. Cohesion is special for each separate substance; it decreases according to distance much more rapidly than the inverse square, vanishing entirely at very small distances. Two such forces have not sufficient kindred to be generalized into one force; the generalization is only illusory; the statement of the difference would still make two forces; while the consideration of one would not in any way simplify the phenomena of the other, as happened in the generalization of gravity itself.

Again, gravity, considered as a power to put masses in motion, to generate visible or moving force, may be compared, by way of an attempt at assimilation, with the equally familiar mode of begetting motion by *impact*, or the stroke of a mass already in motion; as in propelling a ball by a mallet. Here too, however, we have, with similarity of result, a total contrast in the mode. Gravity draws bodies together from a distance; impact must be supposed to urge them through their atomic repulsions. When the expanding gases of kindled gunpowder blow a bullet through the air, there is no actual contact of the parts; there is merely the operation of powerful forces of mutual repulsion, acting, however, at very short distances, like the cohesion of solidity. Now, there appears to be nothing in common to gravity and these atomic repulsions, except the result. We have, therefore, no basis for assimilation or inductive generalization in such a comparison. The two modes of action must be allowed to lie apart in physical science; they must be embodied in different statements or laws, with no hope of being ever brought together.

It is because gravity does not assimilate with the propulsion of impact from a blow or a stroke that people have accounted it mysterious. In point of fact, there is no more mystery in the one than in the other. Attraction, from great distances, is one form of the production of force; Repulsion, at near distances, is another form. The last of the two is, on the whole, most familiar to us; it is the genus that our own physical force belongs to; and we, by a mere whim, suppose it a simpler and more intelligible mode of exerting power; the truth being that, in all that regards simplicity and intelligibility, gravity has the advantage. It is only by confining ourselves to the superficial glance of bodies coming into close contact, thence giving and receiving momentum, that we

suppose this mode of exerting force a simple one; the interpolated links of molecular repulsion are much more complicated than gravity.

A similar line of remarks would apply to any endeavour to assimilate gravity with the Correlated Forces generally. These forces by their nature counteract gravity. The various movements in nature are explicable by the conflict and mutual action of two great Powers; Gravity, on the one hand, and the sum total of the Correlated Forces, molar and molecular on the other. The Correlated Forces mostly appear under the guise of repulsions, as, for example, heat; so much so that this must be considered their typical manifestation; the electrical and magnetic attractions are exceptional, and are probably mere superficial aspects of the deeper fact of repulsive separation.

Three departments of Force thus stand out so distinct as to be incapable of assimilation :—Gravity, the Correlated Forces, and Molecular Adhesion. This last appears under two forms;—the attraction between particles of the same substance—iron for iron, water for water; and the attraction between two substances—as iron for lead, water for alcohol or for common salt. There may be a possibility of generalizing these two, or stating them as a common force. Some approach has been made to this in the fact that the second kind of attraction holds between bodies nearly allied—as metals with metals, earths with earths.

8. The ultimate laws of Nature cannot be less numerous than the ultimate feelings of the human mind.

This, as Mr. Mill pointed out, is the insurmountable barrier to generalization, and consequently to explanation. Whatever number of distinct states of consciousness, not mutually resolvable, can be traced in the mind, there must be that number of ultimate facts or elements of knowledge, and of ultimate laws connecting those states with their causes or concomitants. If the sensation of colour be radically distinct from the feelings of resistance, of movement, of form, there must be a separate law with reference to colour. The phenomenon called whiteness cannot be resolved into the phenomenon of form, or of motion.

Even if we found that the fact of whiteness is conditioned by a certain molecular structure, and certain molecular movements, we should not thereby resolve whiteness into movement; the facts would be distinct facts, although joined in nature.

So, we are aware that the sensation of sound is conditioned by a vibratory movement of the particles of a sounding body; but the vibration is not the sound; all we can say is that a law of causation relates the vibration to the sound. Now there must always remain one law connecting the molecular movements of bodies with the sensation of whiteness, and another law connecting molecular movements with the sensation of sound.

In so far as all sensations are generalized into a common fact of sensation, having similarity with diversity, so far may we generalize the laws that connect sensation with corporeal activities. This is a real and important step of generalization. Yet it does not supersede the necessity of other laws for connecting special and irresolvable modes of sensation with their special seats of corporeal activity. We may have a law of pleasure and pain generally; yet we need laws for the distinct modes of pleasure and pain—the pleasures of light, of sound, &c.—inasmuch as these cannot be resolved into each other.

The great generalities relating to Force all refer to *one sensibility* of our nature—the muscular, or the active side; owing to which fact, they may admit of unity of law, or a common statement. Likewise, there may be unity of law as regards Light and Colour, provided all the modes and varieties are resolvable into the variation in degree of some fundamental mode of consciousness. If there be several fundamental modes, there must be a law for each; thus there may be wanted one law for white light, with its degrees, and one for each of the primary colours—four laws for the sense of sight.

We may be able to discover how Heat causes Light to the extent of generalizing the molecular condition of luminosity, and connecting this with the molecular condition of high temperature; but that such molecular condition and its accompaniments—radiation, refraction, &c. — should yield the sensation of light, must always be expressed in a distinct law, a law uniting an objective with a subjective experience. Such is the proper goal or end of our knowledge in regard to the phenomenon.

FALLACIOUS AND ILLUSORY EXPLANATIONS.

¶ 9. One form of illusory explanation is to repeat the fact in different language, assigning no other distinct yet parallel fact.

This is ridiculed in Moliere's physician, who gives as the reason why opium causes sleep, that it has a soporific virtue.

Not much is done to explain the greenness of the leaf of plants by saying that it is due to a substance named 'chlorophyll.' The only step gained is the fact (if it be a fact) that greenness in all plants is due to the same substance.

A simile is sometimes offered for an explanation. Black's *Latent* Heat was merely a re-statement of the fact: he might have gone on to call it secret, concealed, embodied, shut-up Heat; all which expressions would merely iterate the circumstance that a certain amount of heat no longer appeared as heat to the sense, or to the thermometer.

It is with the great ultimate generalizations, such as the Uniformity of Nature, and the Axioms of Mathematics, that we are most prone to give as a reason, or proof, a mere various wording of the principle itself. 'Why must the future resemble the past?' 'Because Nature is Uniform.'

The phenomenon, sleep, was referred by Whewell to a *law of periodicity* in the animal system. This, however, does nothing but repeat the fact to be explained; there is no assimilation with another fact, so as to yield a higher generality, which would be inductive explanation, and no reference to a higher generality already formed, which would be deductive explanation. A step towards real explanation is made by comparing it with the repose or quiescence of the organs after any activity whatsoever. This is to assimilate the phenomenon with another distinct phenomenon; the two taken together form a higher generality, which, so far as it goes, is an explanation.

10. Another illusion consists in regarding phenomena as simple because they are familiar.

Very familiar facts seem to stand in no need of explanation themselves, and to be the means of explaining whatever can be assimilated to them.

Thus, the boiling and evaporation of a liquid is supposed to be a very simple phenomenon requiring no explanation, and a satisfactory medium of the explanation of rarer phenomena. That water should dry up is, to the uninstructed mind, a thing wholly intelligible; whereas, to the man acquainted with Physical science, the liquid state is anomalous and inexplicable. The lighting of a fire, by contact with a flame, is a great scientific difficulty; yet few people think it so. A soap bubble is a conflux of unexplained phenomena. Voluntary action, from familiarity, has long been reckoned so simple in

itself as to have provided a satisfactory explanation of all other modes of generating mechanical force.

11. The greatest fallacy of all is the supposition that something is to be desired beyond the most generalized conjunctions or sequences of phenomena.

It is supposed by many that the possession of a supreme generality on any subject is insufficient; the mind, it is said, craves for something deeper, and this craving (which can never be satisfied) is considered to be proper and legitimate. The generalization of Gravity leaves behind it a sense of mystery unsolved, as if there were something farther that we might arrive at if obstacles did not intervene.

Newton seemed unable to acquiesce in gravity as an ultimate fact. It was inconceivable to him that matter should act upon other matter at a distance, and he therefore desired a medium of operation, whereby gravity might be assimilated to Impact. But this assimilation has hitherto been impracticable; if so, gravity is an ultimate fact, and its own sufficing and final explanation.

The acceptance of the law of universal gravitation as a full and final solution of the problem of falling bodies, without hankering or reservation, is the proper scientific attitude of mind. There seems no hope at present of making it fraternize with a second force, and there is no other legitimate outgoing of enquiry with reference to it.

In the same way the mysteriousness often attributed to Heat, is partly resolved by the Theory of Correlated Forces, under which heat is assimilated to movement. The subjective fact of heat—the sensation of the mind so described, is a fact coming under the general relationship of body and mind.

Light is still a mystery in the legitimate sense; it has been but imperfectly generalized as regards its physical workings. Every isolated phenomenon is, in the proper acceptation, a mystery.

Apparent contradiction is something that demands to be explained; investigation should never stop short of the attainment of consistency. Thus, the glacial period of the earth's history, is at variance with the only hypothesis yet framed as to the solar agency—the slow but gradual cooling in the course of ages.

The molecular aspect of the Correlated Forces is *repulsion* (as in Heat), yet in Magnetism and in Friction Electricity, it appears as attraction.

Free-will is often stated as a hopeless and insoluble contradiction. To leave any problem in such a condition is unscientific.

The union of Body and Mind has long been considered *the* mystery by pre-eminence. The prevailing opinion has been that this connexion would for ever resist and paralyze explanation. Yet, the scientific mode of dealing with the case is clear. The material properties and the mental properties are each to be conceived according to their own nature—the one by the senses, the other by self-consciousness. We then endeavour to assimilate and generalize to the utmost each class of properties; we generalize material properties into inertia, gravity, molecular forces, &c.; we generalize mental properties into pleasures, pains, volitions, and modes of intelligence. We next endeavour to rise to the most general laws of the union of the two classes of properties in the human and animal organization. When we succeed in carrying this generalizing operation to the utmost length that the case appears to admit of, we shall give a scientific explanation of the relationship of body and mind. Any farther explanation is as incompetent, as it is unnecessary and unmeaning.

Such language as the following is unscientific:—'Conscious sensation is a fact, in the constitution of our corporeal and and mental nature, which is absolutely incapable of explanation.' The only meaning attachable to this is, that bodily facts and mental facts are fundamentally distinct, yet in close alliance. So—'To this day, we are utterly ignorant how matter and mind operate upon each other.' Properly speaking there is nothing to be known but the fact, generalized to the utmost.

'Is there' says Hume 'any principle in all nature more mysterious than the union of soul and body; by which a supposed spiritual substance acquires such influence over a material one, that the most refined thought is able to actuate the grossest matter?'

Again, 'we know nothing of the *objects themselves* which compose the universe; our observation of external nature is limited to the *mutual action* of material objects on one another.' What is the good of talking of a supposable, and yet impossible, knowledge? *

* See FERRIER'S Remains (vol II. p. 436), for some pertinent remarks on the nature of Explanation.

CHAPTER XIII.

HYPOTHESES.

1. Various meanings belong to the word Hypothesis.

I. It means the suppositions, suggestions, or guesses, as to any matter unknown, leading to experimental or other operations, for proof or disproof.

In the course of a research, many suppositions are made, and rejected or admitted according to the evidence. Kepler made an incredible number of guesses as to the planetary relations before he discovered the actual laws. Davy supposed the alkalies to be compounds before he established the fact by decomposing them.

In the Inductive operation of arriving at general laws, the supposition made is some law that appears likely to explain the fact, as Kepler's Third Law (of periodic times and mean distances). Such suggested laws have to be duly verified according to the Experimental Methods.

In the properly Deductive operation of carrying out a law by bringing cases under it, the supposition is an *identity*, as in the examples already given under the Deductive Method. The hypothesis of a man's being guilty of a certain crime is of this nature; the proof consists in the tallying or fitting of the circumstances of the accused with the circumstances of the crime (commonly called 'circumstantial evidence'). Of the same nature is 'the hypothesis of Wolfe with respect to the origin of the Homeric poems; the hypothesis of Niebuhr, with respect to the derivation of portions of the early Roman history from ballads or epic poems; the hypotheses of Eichhorn, Marsh, and others, with respect to the origin of the text of the four gospels; the hypothesis of Horace Walpole, with respect to the character of Richard the Third, and various hypotheses with respect to the Man in the Iron Mask. So there are hypotheses, in literary history, as to the authorship of certain works, as the Aristotelian *Œconomics*, the treatise *De Imitatione Christi*, the *Letters of Junius*. In each of these cases a supposition is made, the truth of which is tried by combining it with all the circumstances of the case.'

These cases contain no matters for logical discussion. They do not raise the questions that attach to the Undulatory Hypothesis of Light, the Development Hypothesis, the Atomic Theory, and other celebrated hypotheses.

2 The definition of a Hypothesis (according to Mill) is a supposition made (without evidence, or with insufficient evidence of its own) in order to deduce conclusions in agreement with real facts; the agreement being the proof of the hypothesis.

Hypothesis, in this sense, is a defective kind of proof; there is some missing link; and the question is raised, how shall this be made good in other ways.

For example, in the geological investigation concerning the transport of erratic boulders, there are various possible suppositions—icebergs, glaciers, water currents. Now, we may be unable to get what we should desire, in accordance with the strict course of experimental elimination, namely, proof of the actual presence and operation of one or other of these agents. The only resource then, is to compare the appearances with what would result from the several modes of action. If these appearances are consistent with one mode only, there is a certain strong presumption in favour of that one. The presumption would obviously amount to certainty, if we have had before us (what we cannot always be sure of having) all the possible or admissible agents.

In the absence of proof as to a man's real motives, on a given occasion, we often decide in favour of some one, because the man's conduct is exactly what that motive would dictate. The soundness of the criterion depends upon there being no other motive or combination of motives that would have the same effects.

§ 3. It is manifestly desirable, in assumptions relating to natural agencies, that these should be known to exist. The Hypothesis is then limited to such points as—their presence, their amount, and the law of their operation.

Such are the hypotheses as to the erratic boulders. So, we may ascribe an epidemic to excessive heat, to moisture, to electricity, to magnetism, to animalcules, to bad drainage, to crowded dwellings, or to some combination of these. The agencies are real; every one of them is what Newton termed a *vera causa*. What is hypothetical is the actual presence of

one or other, the mode of operation, and the sufficiency to produce the effect. If all these could be established in favour of one, the point would be proved. If the presence cannot be proved (the difficulty in *past* effects), there must be shown an exclusive fitness in some one to account for the appearance.

The illustrious example of Gravity may be quoted in its bearing on Hypotheses. Newton's suggestion was, that celestial attraction is the same force as terrestrial gravity. He thus proceeded upon a real or known cause; the hypothetical element was the extension of gravity to the sun and planets.

The preliminary difficulty to be got over was the rate of decrease of the force according to distance. From Kepler's laws, it was proved that celestial attraction diminishes as the square of the distance increases. Was this true of the earth's gravity? The fall of the moon was the criterion, and exactly coincided with that supposition. Thus, then, the law of the sun's attraction and the law of the earth's attraction are the same. The earth's attraction extends to the moon; may it not extend to the sun, and may not the sun reciprocate the very same attraction?

The wonderful amount of tallying or coincidence in this case was sufficient in the minds of all men to justify the assumption that the two attractions are the same. The hypothesis was proved by its consequences. And, as no rival supposition has ever stood the same tests, the Newtonian theory is considered as beyond the reach of challenge.

The rival hypothesis to gravity, in the explanation of the celestial motions, was the Cartesian vortices, or whirlpools of ether, which floated the planets round, as a chip revolves in an eddy of a stream.

The identity here assumed is between the circular motion of the planets, in what is commonly supposed to be empty space, and the circular motion of a whirlpool of water or of air.

The first obvious disparity respects the fluid medium. In the whirlpool of water we have a liquid mass with density sufficient to buoy up wood, and mechanical momentum sufficient to propel it in the direction of the stream. No such fluid mass is known to be present in the celestial spaces; the very supposition is hostile to all familiar appearances. A fluid sufficient to move the planets at the rate they move in would have numerous other consequences that could not escape detection. It would mix with our atmosphere as an active element and produce disturbances on the earth's surface.

In this vital circumstance, therefore, the comparison fails; the assimilation is incompetent.

A second disparity was brought to light in Newton's criticism of the scheme. The laws of a whirlpool are not the laws of the planetary orbits; a whirlpool is incompatible with the laws of Kepler. Now, we cannot assimilate two mechanical phenomena, two attractions, for example, unless they follow the same law of force. This is a vital point in a mechanical comparison. The following of the same dynamical law was the crowning circumstance of the likeness between gravity and solar force.

It would be said, therefore, that the Cartesian scheme did not assign a *vera causa*. It assigned, no doubt, a mode of action quite familiar to us; whirlpools are a real fact. But it assumed a material substance unlike anything hitherto discovered; water we know, and air we know, but the entity demanded for the vortices is entirely foreign to all our experience of material things.

4. As it would seem irrational to affirm that we already know all existing causes, permission must be given to assume, if need be, an entirely new agent. The conditions of proof are, in this case, more stringent.

The chief example of this kind of Hypothesis is the Undulatory Theory of Light.

The supposition of an etherial substance pervading all space, and by its undulations propagating Light and Heat, as the air propagates sound, is in accordance with many of the facts of Light, more especially what is called the Interference of Light, a generalization of many distinct appearances. The hypothesis also served to discover new facts of luminous agency.

Assuming what is not strictly accurate as yet, that the undulatory hypothesis accounts for all the facts, we are called on to decide whether the existence of an undulating ether is thereby proved.

We cannot positively affirm that no other supposition will explain the facts; what we can say is, that of all the hypotheses hitherto suggested, this approaches the nearest to an exact explanation. Newton's corpuscular hypothesis is admitted to have broken down on Interference; and there is at the present day, no rival.

Still, it is extremely desirable in all such hypotheses, to find some collateral confirmation, some evidence *aliunde*, of the supposed ether. This is supplied in part by the observations

on the comet of Encke. If the retardation of that comet, and other observations of a like nature, establish the fact of a resisting or inert medium, there will remain, as hypothetical, the properties of that medium, namely, the peculiar mode of elasticity fitted for transmitting luminous and other emanations.

There is farther to be urged, in support of the hypothesis, its constancy with the other hypothesis that regards Radiant Heat and Light as the propagation of molecular movements from hot and luminous bodies. The transmission of these influences through space, by the communication of molecular impulse, is in harmony with their character as motions in the molecules of the masses of ordinary matter.

An additional confirmation is supplied in the remarkable fact that bodies, when cold, absorb the same rays (of the solar spectrum) that they give out when hot. This is precisely analogous to the law of musical strings, namely, that, of the notes sounded by another instrument in their neighbourhood, they assume each its own note.

§ 5. Some Hypotheses consist of assumptions as to the minute structure and operations of bodies. From the nature of the case, these assumptions can never be proved by direct means Their only merit is their suitability to express the phenomena. They are *Representative Fictions.*

All assertions as to the ultimate structure of the particles of matter are, and ever must be, hypothetical. Yet we must not discard them because they cannot be proved; the proper criterion for judging of their value is their aptness to represent the phenomena. That Heat consists of motions of the atoms can never be directly shown; but if the supposition is in consistency with all the appearances, and if it helps us to connect the appearances together in a general statement, it serves an important intellectual function.

The phenomena of the solid, liquid, and gaseous state of matter can be represented by the opposing play of two sets of forces—the attraction of cohesion inherent in the atoms of each substance, and the repulsive energy generated by the heat motions. In crystals, the heat motions are at a minimum, and in that case, the cohesion assumes a polar character, or is concentrated at particular points, whose difference of relative situation makes difference of crystalline form.

The Undulatory hypothesis of Light, even although it may never be fully established as fact, will have a permanent value

as a Representative summary of the facts of Light; and may be gradually carried to perfection in this character.

In a paper by Graham, on the 'Molecular Mobility of Gases,' published in the Transactions of the Royal Society, 1863, there is put forward a hypothesis of the Constitution of Matter. The assumptions are these:—

(1) The various kinds of matter may consist of one species of Atom or molecule, having a different kind of movement in each substance. This is in harmony with the equal action of gravity upon all bodies.

(2) The greater the energy or swing of the primordial and inalienable movements of the ultimate atoms, the lighter the mass. The leading fact named Density or specific gravity is represented by this assumption.

(3) These ultimate molecules, whose primitive movement gives specific gravity, are supposed to be made up in groups, each group having a farther movement, vibratory or other; which second superinduced movement represents the gaseous molecule affected by Heat, and leading to gaseous expansion. This Graham also calls the *diffusive* molecule.

(4) Equal volumes of two forms of gaseous matter, irrespective of weight, have a facility of combining; this is Chemical Combination. It is a hypothetical expression of the law connecting Atomic Weight with Gaseous Volume. The gaseous state is expressed by Graham as the typical state of matter; 'the gas exhibits only a few grand and simple features.'

The special point of the hypothesis consists in assuming motions within motions, like primary and secondary planets. There is no limit to the successive groupings and their characteristic movements. For still more complex properties, new groupings may be assumed.

A somewhat different hypothesis of Molecular Motions has been given by Mr. Clark Maxwell (Phil. Trans. 1866). It might be superadded to Graham's.

Under the methods of CHEMISTRY, we shall advert to the hypothesis named The Atomic Theory; and under the methods of BIOLOGY, there will occur other examples of celebrated hypotheses. Also, in the Logic of MEDICINE, the representative conceptions are brought under review.

The political fiction as to a Social Contract, determining the rights of sovereignty, is not entitled to the dignity of a Hypothesis. It is a pure fabrication to serve a political, or

even a party purpose; and ranks with the legends in the ancient Grecian states, relied on as giving validity to the title of a tribe to its territory, or of a family to the sovereign power.

16. It has been said (by Dugald Stewart and others) that the reasonings of Geometry are built upon *hypotheses*. The meaning is, that the figures assumed are abstractions, or ideals, and do not correspond to any real things.

The word 'hypothesis,' is here employed in a somewhat peculiar sense. It is identical in meaning with 'Abstract,' as opposed to actual or 'Concrete' objects The important truth intended to be conveyed would probably be given much better by avoiding the use of 'hypothesis.'

In Geometry, as in all Abstract Reasoning, the essence of the operation is to view the things in one exclusive aspect, or with reference to one single property, although, in point of fact, no object exists possessing that property in pure isolation. The geometrical Point is a mark of position; we reason upon it solely as marking position. Every real point, and even the point that we conceive in the mind, possesses at the same time a certain magnitude, a certain colour, and certain material substance. We, however, make abstraction of all these features; we do not assume them in any degree; we drop them entirely out of view; we consider 'position,' *in so far as* 'position,' and make affirmations on that special assumption. When we come to deal practically with an actual point, we must re-admit all these properties belonging to it in its concreteness; we must allow for the fact that no actual point can determine an abstract position; it covers an area, and therefore does not fix position except by an approximation.

In Mechanics, there are convenient fictions that subserve the abstract reasonings of the sciences; as, for example, the supposition that the whole mass of an irregular body is condensed into its Centre of Gravity—an operation impossible in fact, but having a practical convenience in mechanical demonstrations. It is desirable, for certain purposes, that we should make abstraction of the form and size of a mass, and view only its weight and its relative position to some other mass; and one way of compassing the end is to imagine the form and the size non-existent, or that the mass exists in a mathematical point. We say there is a certain definite position in the interior of the earth, wherein, if the whole mass were

concentrated, the earth's attraction for the sun and the moon would be the same as it actually is. This is merely a verbal aid to the process of reasoning in the Abstract. The remark is applicable to all the other abstract centres—oscillation, suspension, gyration, &c.

7. A fact that decides between two opposing Hypotheses was called by Bacon an *experimentum crucis.*

The 'Instantia Crucis' of Bacon does not properly belong to the Experimental Methods of Induction. It is the decisive instance between two contending hypotheses. Thus, when the Copernican system was brought forward in opposition to the Ptolemaic, not only was there a necessity for showing that the new system corresponded with all the facts; there was farther required the production of some facts that it alone could conciliate. The first fact of this decisive character was the Aberration of Light, a fact incompatible with the earth's being at rest. Another fact, equally decisive, is furnished by the recent pendulum experiments of Foucault with regard to the motion of the earth. Bacon himself, who never fully accepted the Copernican system, desiderated an 'experimentum crucis' of this nature, namely, a fact to show that the velocities of bodies appearing to move round the earth are in proportion to their distance; which, he says, would be a proof that the earth stands still, and that the apparent daily motion of the stars is real.

The entire absence of mechanical energy in the rays of light is regarded as decisive against Newton's Emission Hypothesis. The most delicate experiments fail to show any moving energy in the concentrated rays of the sun; which failure is inconsistent with a stream of particles of inert matter.

CHAPTER XIV.

APPROXIMATE GENERALIZATIONS AND PROBABLE EVIDENCE.

1. Probable Inference is inference from a proposition only approximately true.

Every certain inference supposes that the major is a proposition universally true, as 'all men are mortal,' 'all matter

gravitates.' When a minor is supplied to such propositions, the conclusion is certainly true.

From a proposition true only in the majority of instances, the inference drawn is not certain, but only probable. 'Most (not all) phenogamous plants have green leaves;' hence it is probable that any given class of these plants has green leaves.

The word for such generalities is 'most;' the synonyms are 'many,' 'usually,' 'commonly,' 'generally,' 'for the most part,' 'in the majority of instances.'

2. If we know the exact proportion of cases in an approximate generalization, we can state numerically the degree of probability of an inference drawn from it.

It being known that a certain thing happens in nine instances out of ten, the probability, in a particular case, is nine to one, or nine-tenths. All the metals, except copper and gold, are devoid of colour, (being either white or some shade of grey). The probability that a new metal is white or grey is as fifty-two to two.

On the supposition that the majority of drunkards are never reformed, the probability is against the reform of any individual drunkard. The strength of the probability depends upon our estimate of the comparative numbers. If this estimate is vague and uncertain,—if we cannot say whether the reformed drunkards number one fiftieth, one twentieth, or one-fourth of the whole,—our estimate of the probability in the given instance is correspondingly vague.

What Hobbes says of Charles II—

> Nam tunc adolescens
> Credidit ille, quibus credidit ante Pater—

is true of the vast majority of men even in the most enlightened countries. Hence a strong probability that any given individual has never exercised any independent judgment in politics or in religion. A hundred to one is a safe estimate of such a probability.

It is an approximate generalization that both intelligence and independent thought are most frequent in the middle ranks of society. The generalization has in its favour deductive as well as inductive evidence. We know the circumstances adverse to those qualities in the highest, and also in the lowest, ranks. Still, it is but approximate, and yields only probability in every given application. Like all probabilities, however, if applied to masses, it gives certainty. The

collective action of a middle class body would be more intelligent and independent than the action of the other classes.

The proposition is approximately true that the wealthy are more virtuous than the indigent. There are numerous exceptions, but the evidence is sufficient to prove the rule as an approximate generalization. The only dispute is as to the extent of it. Direct statistics on the great scale are wanting; and the deductive argument consists in comparing the tendencies for and against virtue in the wealthy, as compared with the poorer class—a comparison where, from the vague nature of all estimates of human conduct, a certain latitude of expression must be allowed.

The characters of men are described by such general terms as energetic, timid, tender-hearted, irascible, truthful, intellectual, and so on. Even when most carefully generalized, these characters are only approximate; they represent prevailing *tendencies*, liable to be defeated in the complicacy of human motives. So with classes, professions, and nations. All the current generalities respecting the characteristics of sex and of age are mere approximations. Literary and Art criticism, as expressing the style and manner of authors or artists, is of a like nature.

The operation of laws and institutions is at best but approximate. We cannot affirm that the general good consequences follow in every instance. The tendency of severe punishments is to deter from crime; they may do so in nine cases out of ten, or ninety-nine out of a hundred. It is the duty of the state to seek out the mode that approximates most to the desired end. In such a case, statistics give a kind of numerical precision to the general tendency, and a corresponding exactness to the inference of probability.

The very best institutions have to be defended on the ground of superior good, not of absolute or unexceptional good. This is all that can be said for liberty as against restraints, for responsible government as against despotism.

Proverbial sayings are for the most part but rude approximations to truth. Many of them can hardly be said to have a preponderance of cases on their side. 'The more haste, the less speed' is not true in the majority of instances; its merit is chiefly as an epigrammatic denial of the universality of the rule that activity succeeds in its object. We often take delight in parading the exceptions to approximate generalities; and not a few of our proverbs are occupied with the representation of minorities. Tallyrand's 'No zeal' is incorrect as a rule;

the rule that it crosses, however, is but approximate, and has exceptions; the point of the saying lies in suggesting these.

§ 3. It is a legitimate effort to endeavour to make the approximation of a rule as close as possible, before applying it to cases. This can be done in various ways.

(1) An approximate generalization is rendered absolutely certain in its scope, when all the exceptions can be enumerated; as in grammar rules, and in Acts of Parliament containing schedules of exceptions.

(2) A very near approximation can be made if we know the exact occasions and circumstances where the rule holds. Thus that 'Honesty is the best policy' is in the abstract only a rough generalization; it is far from the exact truth. But we are able to assign the specific circumstances where it holds good more nearly. The 'honesty' should exactly correspond to the standard of the time, not rising above, and not falling below the established code. It should be apparent and not concealed from view. It should contribute something to the advantage of persons of weight and influence. Thus limited and qualified, the approximation is very near the truth; yet not altogether true. The dishonest successful men are still sufficiently numerous to constitute a standing exception to the maxim.

The Proposition 'Knowledge is virtue' was maintained in the Socratic school. It is an appproximate generalization, giving a certain small probability in its applications. That it has the truth on its side is proved by the statistics of crime; the majority of criminals coming from the least instructed part of the population. Still, the exceptions are numerous. We know from deductive considerations that virtue does not spring directly from the knowing faculties; the filiation is indirect or circuitous. The best application of so slight a probability is to take it with concurring probabilities. The conditions of a virtuous character can be stated with considerable precision, while intellectual culture also is an element whose value can be assigned. Hence, in applying the rule to a known case, we can infer with a far higher probability, than could be given by any one approximate generality, as to the virtuous tendencies of knowledge, of parentage, of occupation, and other circumstances. We can unite all the presumptions into one still stronger.

It is a usual defect of empirical generalities that the subject of them is badly defined, or that the circumstances where

the predicate holds cannot be exactly specified. This is a common defect in the practice of medicine. A drug has a certain efficacy in the majority of instances, and is therefore only probable in its consequences. A higher knowledge would give the exact conditions wherein it succeeds, which would be to convert the approximation into certainty.

So in Politics. Certain institutions, as for example Free Government, are good for nations generally. In some cases, they fail. It is for political science to specify accurately the circumstances where they are suitable, and those where they are unsuitable; by which means we may attain to rules of a certain, or nearly certain character.

It is commonly said that being educated at a public school developes particular manly virtues, as self-reliance, courage, &c. This is but an approximate generalization. If we had the comparative numbers of the successes and the failures, we could assign the probability in a given instance. Still better, however, would be the enquiry, what are the circumstances wherein the effect would arise; what kind of youths would be operated on in the salutary way?

It is an approximate generalization that absolute sovereigns abuse their power; it is true, in a large majority of instances, but not in all instances. It can be converted into a still closer approximation, if we can assign the particular situation of an individual sovereign—the motives operating upon him personally, either as encouraging or as checking the despotic vices. Hence, by a series of *provisos* (as Mr. Mill remarks) we may render an approximate rule, an almost certain rule:—An absolute monarch will abuse his power, *unless* his position makes him dependent on the good opinion of his subjects, or *unless* he is a person of unusual rectitude and resolution, or *unless* he throws himself into the hands of a minister possessing these qualities.'

4. Approximate generalizations give an opening to the bias of the feelings, and to the arts of a sophistical reasoner.

It is impossible to deal fairly with an approximate generalization, except by forming some estimate, the best that can be had, of the instances on one side and on the other. This is often difficult even to the most candid and painstaking truth-seeker. Nothing then is easier than to turn away the mind from a part of the instances, and to decide upon the remainder. Any strong feeling has this blinding efficacy. For example, our Patent Law has raised a certain number of

persons to wealth; it has stimulated a certain number to inventions, whether profitable or not to the inventors; it has induced a certain number to waste their lives in unproductive and hopeless enterprises: it has obstructed, in certain instances, the introduction of improvements. Whether the law has been good or evil on the whole, depends upon the *relative number* of these various instances. Now, it would be most difficult to attain an exact comparative estimate in such a question. How easy then for any one to incline to the instances favouring a preconceived theory, and to pay no heed to the rest?

The arts of the pleader suit themselves to this situation. By dwelling upon and magnifying the instances in one side, by ignoring and explaining away those in the other, a skilled advocate reverses the state of the numbers in the approximate generalization, making the minority seem the majority. The reply needs to be conducted so as to redress the distorted estimate. (For the practical applications of Probability to Testimony and other Evidence, see APPENDIX I.).

CHAPTER XV.

ANALOGY.

1. The foundation and justification of all inference is Similarity. The similarity may exist in various forms and degrees, and the validity of the inferences will be modified accordingly.

When two situations are exactly the same, the uniformity of nature leads to the same consequences. Place equal weights in a balance so as to make an exact equipoise. Shift the centre of motion to one end, and that end will rise and the other fall, every time that the change is made. A great deal of variety may be introduced into the experiment, with the same result. The rod may vary in length, and in material, and the weights may be small or great: so that we may have sameness in the result without sameness of the antecedents.

Again, having seen a great many animals die, we infer that other animals living and to be born will die: the resemblance, together with nature's uniformity, being the justification. But there are often wide disparities between the instances observed and the instances inferred.

It was, however, the object of the experimental methods to eliminate the *essential* parts of a causal situation from the non-essential parts. In the midst of all the various forms of the experiment with the balance, we find, by the use of the methods, that the one circumstance that disturbs the equipoise is to remove the point of suspension from its central position in the beam; that the size and material of the beam, the size and material of the weights, are unessential circumstances. So with animal life; the fact called organized life is the fact accompanied with mortality; the forms and sizes of animals, their being vertebrate or invertebrate, are inductively eliminated as unessential.

An inductive inference is thus an inference from sameness in certain particulars, shown by induction to be the particulars always present when some consequence or collateral is present. This is an inference by identity, a *perfect* induction.

2. There may be a radical difference in the subjects of two compared phenomena without preventing a strict Inductive inference. The sole condition is that the sameness apply to the attribute found by induction to bear the consequence assigned.

To say 'there is a tide in the affairs of men' is to use a mere metaphor, the subjects compared being totally distinct. Now, to reason from one subject to another of a different kind, might be called reasoning by Analogy; yet, the inference might be such as to deserve the name of induction. Great as is the difference between the march of human history, and the flow of the tides, still, if the two phenomena exactly resembled in the single feature of ebbing and flowing, and if no inference were drawn, except what this feature involved, the argument would be a sound and strict induction. If human affairs in any way are truly describable as ebbing and flowing, we are entitled from one movement to predict the following. If periods of great public excitement in special topics as Liberty, Religion, aggressive War, are followed by periods of apathy, there is a species of tidal movement, and the laws of the tides may so far be applied to the case, by a legitimate induction, or else by a deduction founded on an induction.

The Chinese profess to found their government on the paternal principle, and to justify their peculiar form of despotism on the similarity of the state to a family. The argument is not inductive; there is a failure in essential points. It is a crude metaphor. There is a certain important similarity,

namely, the fact of government, involving authority, superiority, and punishment; and any inferences drawn upon this single circumstance would be valid. Certain of the merits and of the demerits of government are identical in both instances; the graduation of punishment to offence, consistency and fairness on the part of the ruler to the ruled, are equally required in the family and in the state. But it is not an inductive inference to say that because the parent is despotical, so should the state. The two cases do not agree in the point whence the despotical relation flows; in the family, the subjects of government are children; in the state, the subjects are grown men, on a level with the rulers. The inference would require the case of a very ignorant and degraded community ruled by a wise and high-minded caste To whatever degree a nation approximates to this state of things, there is an identity between it and the family relationship.

Plato's comparison of the state to an individual man is not an analogy in the proper sense of the term. It is one of those figurative resemblances where the points of agreement and of disagreement are perfectly ascertainable, and where there is no element unknown. Any one can tell whether the inferences drawn from the comparison follow from the points of agreement. That there should be a three-fold classification of citizens in the state, cannot be inferred or confirmed by an analysis of the mind into three leading functions. The constitution of a state has nothing in common with the divisions of the mental powers of an individual man

The same remark is applicable to another favourite comparison of Plato's—virtue to health. The resemblance is exceedingly slight; yet, if nothing were inferred but what grew out of that resemblance, we could not object to the use of the comparison. But Plato's theory of punishment derived from it supposes a likeness that does not hold; and the theory is refuted by exposing the dissimilarity.

The Ancient Philosophy was full of these misapplied comparisons, improperly termed analogies.

Speaking with reference to the early growth of Law, Mr. Mayne observes:—'Analogy, the most valuable of instruments in the maturity of jurisprudence, is the most dangerous of snares in its infancy. Prohibitions and ordinances, originally confined, for good reasons, to a single description of acts, are made to apply to all acts of the same class, because a man menaced with the anger of the gods for doing one

thing, feels a natural terror in doing any other thing remotely connected with it. After one kind of food has been interdicted for sanitary reasons, the prohibition is extended to all food resembling it, though the resemblance occasionally depends on analogies the most fanciful. So, again, a wise provision for insuring general cleanliness dictates in time long routines of ceremonial ablution; and that division into classes which at a particular crisis of social history is necessary for the maintenance of national existence degenerates into the most disastrous and blighting of all human institutions—Caste.'

Analogy has been often defined 'resemblance in relations:' as when a wave of water is said to be analogous to an undulation of air, or of ether; or a magnet is compared to a charged Leyden jar because of the common polar condition. This definition is objectionable chiefly on the ground of vagueness. The word 'relation' is too general for a precise statement of the case. What truth or fitness there is in the expression can be given in other ways.

3 Analogy, as different from Induction, and as a distinct form of inference, supposes that two things from resembling in a number of points, may resemble in some other point, which other point is not known to be connected with the agreeing points by a law of causation or of co-existence.

If two substances agree in seven leading properties, and differ in three, the probability of their agreeing in some eleventh property (not known to be connected with any of the ten) is, with reference to the known properties, seven to three. But this rule would be modified by the consideration of the number of properties still remaining to be discovered, a circumstance necessarily indefinite. If we had reason to suppose that a large number of properties still remained undiscovered, the probability could not be stated with the same fixity or confidence.

4. An argument from Analogy is only Probable. The probability is measured by comparing the number (and importance) of the points of agreement with the number and importance of the points of difference; having respect also to the extent of the unknown properties as compared with the known.

No Analogy can amount to full proof; very few give even a high probability. 'It may afford,' says Reid, 'a greater or

less degree of probability according as the things compared are more or less similar in their nature; but it can afford only probable evidence at the best.'

The natural Kinds afford the best examples of the typical case of Analogy. They have numerous properties, known and unknown; extensive agreements prevail among groups of them, together with differences more or less numerous. Thus, sodium and potassium have numerous points of agreement, and a few points of difference. There would, therefore, be a certain amount of probability that any effect due to sodium, or a given compound of sodium, might arise from potassium, or the same compound of potassium.

The celebrated guess of Newton, as to the Diamond, which was afterwards verified by experiment, was not an analogical inference in the strict sense. Had the inference been from a single body, as an oil, to the diamond (the point of agreement between them being unusual refracting power), the resemblance would have been too limited even for a guess. The application to the Diamond was the carrying out of an Empirical Law, partially, if not wholly proved. The circumstance that arrested Newton's attention was that the refracting power of bodies is very nearly as their densities *excepting that unctuous and sulphureous bodies refract more than others of the same density*. Having obtained measures of the refractive powers of the densities of twenty-two substances, varying in density between air and diamond, he found that they fell into two classes. In one class, were *topaz, selenite, rock-crystal, Iceland-spar, common glass, glass of antimony, common air*: in all which, the refracting powers are almost exactly as the densities, excepting that the refraction of Iceland-spar is a little more than the proportion. In the second class were *camphor, olive oil, linseed oil, spirit of turpentine, amber*, which are, 'he said,' 'fat, sulphureous, unctuous bodies,' and *diamond* which 'probably is an unctuous substance coagulated;' all these, compared together, have their refractive powers almost exactly proportioned to their densities. But now, when the two classes are compared, the refractive powers of the second class (the unctuous substances) are twice or thrice as great, in proportion to their densities, as the refractive powers of the first class. *Water* has a middle position between the two classes; *salts of vitriol* may stand between the earthy substances and water; and *spirit of wine* between water and the oils. The suggestion as to the diamond thus arose from its position among a number of highly refracting bodies that

agreed in being of an inflammable or combustible nature. The concurrence of high refracting power with inflammability was an empirical law; and Newton perceiving the law, extended it to the adjacent case of the diamond. The remark is made by Brewster that had Newton known the refractive powers of the minerals *greenockite* and *octohedrite*, he would have extended the inference to them, and would have been mistaken.

As an example of Analogy proper let us suppose the Balsam of Peru to possess certain properties, medicinal or other. Suppose next, that the balsam of Tolu agrees in a great number of these, but differs in one or two important or unimportant properties. On this proposition, we should ground a very considerable presumption, that the one might replace the other in new and untried applications in Pharmacy.

The illustration might be extended to Vegetable and to Animal species. A quadruped resembles a human being in very many points of structure and function, but also differs in a considerable number; while there may be undiscovered properties in both. This reduces to a weak probability all inferences from one to the other as to the suitable kinds of food, liability to disease, or medical treatment. Experiments on animals may cast light on the human subject, provided we know that the particular organs are constructed nearly alike in both, as in the connexions of the nerves, the breathing, the digestion, &c. The function of the saliva and of the gastric juice has been studied by experiments on dogs and on horses. In a recent set of experiments on the action of mercury, dogs were operated on; care having been first taken to ascertain that they agree with human beings in the mercurial symptom of salivation.

It is interesting to determine whether our inference from man to the lower animals as to the possession of consciousness, is an induction or only an analogy. We believe that, in human beings, consciousness is always associated with certain external manifestations, called the signs of feeling, and with an internal structure of brain, senses, and muscular organs. This we hold to be an inductive uniformity completely established as regards human beings. The induction extends to differences of degree; with fewer and feebler manifestations, and a smaller brain than usual, we couple a feebler degree of the mental functions. Now, the physical part is found in the brutes; some approximating more, and some less, closely to the human type. It would seem, therefore, that by induction,

and not by analogy, we are to infer the existence of consciousness in the animals, with modifications of degree only.

Mind and Body are of opposite nature; they are the greatest of all contrasts. Yet there are points of analogy that have been made use of to furnish language and illustration from the one to the other. As in material phenomena, we may have a plurality of forces conspiring or opposing each other, the resultant being arithmetically computable, so in mind we have motives uniting or opposing their strength, the effect being computable (although not with numerical exactness) by adding together those on each side, and noting which is the larger amount. Reid has objected to this comparison, remarking that 'the analogy between a balance and a man deliberating, though one of the strongest that can be found between matter and mind, is too weak to support any argument.' Yet, if the analogy is trusted only to the extent of the similarity, there is no good objection to making an inference from it. Now, the similarity is complete as far as regards the cumulative effect of concurring motives, and the neutralizing or frustrating effect of opposing motives. Whatever power a given motive adds to a man's volition when it concurs, it must subtract or withdraw when it opposes.

The intrusion, by Aristotle and by Kant, of phraseology derived from the intellect, into the domain of the feelings and the will, may be pronounced an improper identification, or an abuse of analogy. Aristotle's *syllogism* of the Will, and Kant's *categorical* Imperative, point to no real resemblance; a syllogism expresses an argument conducted by the reasoning faculty; it has no relevance or suitability to express the decisions of the will.

Reflex Actions may be profitably compared with Voluntary Actions, if we confine ourselves to the points of similarity. The Reflex is the voluntary with consciousness suppressed or made unessential; on the corporeal side, there is a considerable amount of resemblance, or still better, a gradation or continuity.

Until recently, the sun was considered to be only analogically compared to terrestrial fires. The points of agreement, in giving forth radiant heat with light, are of the most essential kind; but there was supposed to be a disparity also vital. It was conceived that the sun gave forth its vast flood of radiance, with no diminution of intensity. Now, every hot body on the earth cools by radiation. Until this serious disparity was got over, scientific men felt that all inferences from

terrestrial bodies to the composition of the sun were rash and unauthorized.

Much speculation has been expended on the question—Are the planets inhabited? The argument is at best analogical; and there is not even the force of analogy except with reference to a small number. Bodies, like the moon, possessing no water and no atmosphere, must be dismissed at once. The planets generally appear to possess atmospheres.

We seem justified, however, in making a summary exclusion of the near and the remote planets, on the ground of temperature. All organized life known to us, is possible only within narrow limits of temperature; no animal or plant can exist either in freezing water or in boiling water. Now, the temperature of Mercury must in all likelihood be above the boiling point, even at the poles, and the temperature of Uranus, and of Saturn, below freezing at the equator. The constituent elements being now shown to be the same throughout the solar system—Carbon, Oxygen, Hydrogen, &c., we are not to presume any such departure from our own type of organized life as would be implied by animals and plants subsisting in these extremes of temperature. On the supposition that the sun's temperature has steadily decreased, and is still decreasing, by radiation, the day of living beings is past for Uranus and Saturn, and perhaps for Jupiter; it is not begun for Mercury.

Confining ourselves, therefore, to the neighbouring planets, and referring to the others only for the periods, past or future, when the capital circumstance of temperature is suitable, we have an analogical argument as follows. Venus and Mars are gravitating masses like the earth, containing, we may now say with certainty, the same materials as this globe—solid, liquid, and gaseous. But we cannot tell the precise arrangement of the constituent substances; and, seeing that with ourselves so much depends upon the mere collocation and amount of such elements as oxygen and carbon, we may consider that the unknown properties of the supposed planets are considerable in number, and serious in character. The probability arising out of the points of agreement, if not greatly affected by known differences, is reduced by this large element of the unknown.

Many Hypotheses are of the nature of analogies or comparisons, the degree and value of the resemblance being more or less uncertain. Thus, to refer to the undulatory hypothesis of Light. When Newton explained the waves of water, and the vibrations of the air in sound, by the oscillations of a pendulum, he was assimilating phenomena of the same mechanical

character, and reasoning only from the points of similarity. But when we reason from the sonorous vibrations of the air to the vibrations of an ether assumed as occupying space, and conveying light and heat, we work by analogy. It would, therefore, not be irrelevant to apply the rule of analogy, and estimate the points of agreement, as compared with the points of disagreement, and conclude accordingly. On this view, the hypothesis would have but a small intrinsic probability; it would be left in a great measure dependent on the kind of evidence already quoted in its favour, the tallying with the special facts of the operation of light.

The first attempt to penetrate the mystery of nervous action was Hartley's hypothesis of vibratory propagation, based on the analogy of sound. The comparison was crude and unsatisfactory; but there was a certain amount of likeness, and the inferences founded on that were admissible. It realized the fact of influence conveyed inwards from the nerves to the brain, and outwards from the brain to the muscles, thus suggesting a *circle of action*, which circumstance alone is pregnant with valuable conclusions, as appeared after the discovery of Bell gave new vigour to the conception. The *vibratory* mode of communication had no relevance, and any conclusions drawn from it were unsound. Next came the analogy to the electric current, which was much closer to the facts, more fertile in suggestions, and less charged with misleading circumstances. By taking liberties with current action, something like the liberties taken with the ether in adapting it for light, we are able to shape a view of nerve force that fits the actual phenomena with remarkable closeness. A third mode of representing the action has been advanced by Mr. Herbert Spencer, which departs from electrical and chemical action and reposes upon the physical property called *allotropism*.

CHAPTER XVI.

CREDIBILITY AND INCREDIBILITY.

1. There are propositions supported by a certain amount of evidence, that are nevertheless disbelieved. From some

circumstance connected with them, they are pronounced INCREDIBLE.

Irrespective of the evidence specifically adduced in favour of a certain fact, we often pronounce it credible or incredible; in the one case we believe, and in the other disbelieve, under the same amount of positive testimony. We believe, on a slight report, that a fishing boat foundered in a heavy gale; we do not believe, without much stronger testimony, that a fully equipped man-of-war was wrecked. It was lately rumoured that the Eddystone lighthouse was blown down; every one felt that the rumour required confirmation.

2. The circumstance that renders a fact Credible or Incredible is its being consistent or inconsistent with well-established inductions.

In simple cases, this is apparent. That a child initiated in crime by its parents should become a criminal, is credible, because it is highly probable, being the result of a well-grounded induction of the human mind. That such a child should turn out a paragon of virtue, as is sometimes described in romance, we pronounce improbable and therefore incredible. In the one case we are satisfied with a small amount of testimony, in the other case, we demand very strong evidence.

We are thus often led to reject evidence at once on the score of antecedent improbability. We may be in the position of refusing a large amount of positive evidence; as when a number of respectable witnesses testify that a man after being immersed in the water for an hour has been resuscitated. It is to be remarked, however, that in all such cases the evidence tendered is only *probable*; it may have a very high degree of probability, it may be 500 to 1, yet it does not amount to certainty. It fails once in five-hundred-and-one times, and is therefore, in certain circumstances, not safe from rejection.

3. Such well-established scientific inductions, as the Law of Gravity and the Law of Causation, render wholly incredible any assertion that contradicts them.

That Mahomet's coffin hung suspended in middle air, that a table of its own accord mounted to the ceiling of a room, are facts to be wholly disbelieved.

All the alleged discoveries of a perpetual motion, or the rise of force out of nothing, are incredible; they are opposed

to Causation as expressed under the Correlation or Persistence of Energy. All supposed modes of deriving motive power, otherwise than from solar heat past or present, are incredible. That any medium of force more economical than the combustion of coal remains to be discovered is all but incredible.

If any one affirms that some change has happened without a cause, we refuse to listen to it. An exception to this rule is sometimes claimed in the case of the human will; but that exception has never yet been established upon evidence sufficient to cope with the evidence in favour of the law of causation.

The principle laid down by Hume, that nothing is credible that contradicts experience, or is at variance with the laws of nature, is strictly applicable to these completely proved inductions. We cannot receive any counter evidence in their case, unless of a kind so strong as to reverse our former judgment and make them out to be mistakes. No mere probability is equal to this task in regard to the axioms of mathematics, the law of causation, the law of gravity, and many others.

That every living thing proceeds from a previous living thing, or as expressed by Harvey—*omne vivum ex ovo*, is an induction verified by simple agreement, through a very wide experience; rendering spontaneous generation, for the present, incredible. It is an empirical law, true within all the limits of human observation hitherto, although we may not be able to extend it over an indefinite period of time.

Among facts antecedently incredible, we must rank the spontaneous combustion of a human being, which is totally inconsistent with the constitution of the animal body.

It has been alleged by witnesses that the mummy corn of the Egyptian pyramids has been sown and been productive. To a botanist, the assertion is wholly incredible. Seeds two centuries old are so completely changed as to lose their fertility.

There appears to be unexceptionable testimony to the practice of the Indian Fakeers, in allowing themselves to be buried for a number of days, after which they are dug out alive. This would be wholly incredible, but for the knowledge that we have of such states as trance, or lowered animation, which dispense with food altogether for a time, and require only the minimum of oxygen.

It is alleged by travellers that certain tribes subsist upon earth as food. This is admissible, only on the supposition that the earth contains a quantity of organic products, such

as starch, sugar, albumen, or their equivalents. That any human being or animal could live upon the purely inorganic matters of the soil is to be wholly disbelieved.

The phenomena of clairvoyance are all in the position of antecedent incredibility. That any one should see with the eyes bandaged is at variance with the conditions of vision as established by all the authentic experience of the human race. Yet this has been affirmed by multitudes of witnesses. The testimony of witnesses, however, in such a matter cannot be received. The sole condition of admitting such a fact would be (what has never yet been attempted) a rigorous verification according to the methods of experimental science. So with the other facts of the same class—prophetic dreams, visions or intimations of events at a distance. These are all opposed to well-established inductions.

4. When a fact with a certain amount of evidence in its favour, is opposed, not to an established induction, but to an approximate generalization or probability, the case is one of computation of probabilities.

What is only probable, or approximately true, has exceptions; an opposite assertion, therefore, may be credited, if supported by a still higher probability, or by a generalization approximating still more to certainty. A fact true ninety-nine times in a hundred is not to be set aside by an opposing testimony correct only nine times in ten.

In an age when physical laws were imperfectly understood, when the law of causation itself was not fully verified, the phenomenon of witchcraft stood between opposing probabilities. There was no inductive certainty on the one hand, to controvert the mere probabilities of human testimony on the other. The physical knowledge even of Bacon was not enough to render the testimonies in support of witchcraft wholly incredible, although it might have stamped these with inferior weight and cogency.

5. The allegations of travellers as to new species of plants, or of animals, are credible or incredible according as they affirm what contradicts, or what does not contradict, laws of causation or of co-existence.

There are certain peculiarities of structure that are involved as cause and effect in the animal system. An animal species must have an organ for receiving and digesting food, a respira-

tory organ, a means of reproduction. Any contradiction to these must be absolutely rejected.

Next in point of evidentiary force are the typical peculiarities of the order, as the four limbs in the higher vertebrata. An animal of the higher tribes, with both wings and arms, would present an incredible combination; there might not be absolute incompatibility, but there would be such a departure from the type as experienced, that it could not be received on less authority than ocular inspection fortified against every possibility of delusion.

New combinations of compatible organs are improbable only in proportion as they have been hitherto undiscovered. Flying fish were improbable, but not to the degree of incredibility. The extension of our knowledge of kinds, by showing new variations, reduces the improbability in favour of other kinds, within the limits of compatibility. That a ruminant animal may be found without cloven hoofs is incredible, if these are cause and effect, or effects of a common cause, it is only improbable if they are co-existences without causation. Such a co-existence has been widely verified, but not as yet exhaustively.

A late distinguished historian for a long time doubted the fact of persons having lived more than a hundred years. He did not regard the fact itself as absolutely incredible; but in the absence of authentic registrations, and the uncertainty of memory and tradition extending to events a century old, he considered that the improbability of so great an age had not been overcome by sufficient counter probabilities. At length he obtained what he deemed adequate evidence in favour of centenarians.

6. The assertion of a fact wholly beyond the reach of evidence, for or against, is to be held as untrue.

We are not entitled to put the smallest stress upon a fact without evidence in its favour, because, from its being inaccessible to observation, no evidence can be produced against it. To affirm that the centre of the earth is occupied by gold, is for all purposes, the same as a falsehood.

On the Great Postulate of Experience, we are to believe that what has uniformly happened in the past will continue to happen in the future; we accept uncontradicted experience as true. But where there has been no experience, we can believe nothing. We are not obliged to show that a thing is not; the burden lies upon whoever maintains that the thing is.

BOOK IV.

DEFINITION.

The processes having reference to the class, notion, or concept, have been already enumerated. The chief are, Classification, Abstraction, Naming (with a view to generality), Definition.

The class, notion, or concept as already explained, is a product of generalization. It may be constituted by one common property, as resisting, moving, white, bitter; or by more than one, as house, mind, man.

√CLASSIFICATION, in its simplest form, follows the identification of like things; that is, a class is made up of things brought together by likeness. When the mind attends more particularly to the points of community, it is said to put forth the power of ABSTRACTION. A name applied to the class in virtue of the class likeness, is a GENERAL NAME. The precise delineation of the likeness by a verbal statement is DEFINITION.

The three processes—Classification, General Naming, and Definition—are what we are now to consider. The first-named process, Classification, has a larger meaning than the mere assemblage of things upon one or more points of likeness; it includes the arts for systematically arranging vast multitudes of related objects, under higher and lower genera, as in what are called the three Kingdoms of Nature. With a view to this greater complication, we shall view the whole subject of Classification last of the three.

As regards the generalization of the Class, or Notion, in all its aspects, the fundamental principle is stated as follows:—

Of the various groupings of resembling things, preference is given to such as have in common the most numerous and the most important attributes.

This is the basis of natural or philosophical classifications,

in contrast to insignificant and unsuggestive classifications; as in the distinction between the Natural and the Linnæan systems of Botany. It may be termed the golden rule of classifying.

We are often disposed to prefer classes on account of their extent, although the common attributes—the comprehension or connotation, may have dwindled down to a limited and unimportant resemblance. Thus, the class 'land animals' is very extensive, with little comprehension; and more insight is imparted by breaking it up into groups, as mammalia and birds, each having numerous and important points of community. The class 'adherents to a religious creed' is so wide as to impart very little information respecting the individuals; the sub-classes Buddhists, Mahometans, Jews, Roman Catholics, Calvinists, each connote a large circle of peculiarities.

CHAPTER I.

CANONS OF DEFINITION.

1 Definition consists in fixing by language the precise signification—the Connotation—of General Names.

Defining does not apply to the unmeaning name. An arbitrary name used for a particular object as 'Sirius' for a star, 'Snowdon' for a mountain, 'Samson' for a locomotive, is explained only by showing or indicating the thing.*

Nevertheless, from the important consideration already stated (Introduction, p. 6), that even a singular is conceived by the mind as a conflux of generals, Definition becomes eventually applicable to individual things. A particular star, a mountain, a locomotive engine, may be represented and marked off from all other things by a series of descriptive names of general signification. For such an operation, however, the name *Description* is more appropriate.

It has been already explained (Part I., p. 71) that a perfect Definition is the whole connotation of the name. Some notions have one point of community; some two, three, or four; some a great many, as the often-mentioned Kinds; the proper and

* Hence the maxim of the old logicians, 'Omnis intuitiva notitia est definitio'—'a view of the thing itself is its best definition.'

complete Definition must give an account of them all. The singling out of one or two properties, for the mere purpose of discrimination, is not a proper or perfect definition.

2. From the very nature of human knowledge, Definition appeals to the two fundamental principles—Agreement and Difference, or Generality and Contrast.

I. Every generality must relate to particulars.

II To every real notion, as well as to every particular experience, there corresponds some opposite, also real. This is simply the Law of Relativity or Contrast.

As the statement of what is common to a number of particular things, Definition is essentially a process of generalization; while neither particular things, nor their agreements, have any distinct meaning, unless there be assignable a distinct opposite. The act of Defining, therefore, consists of a generalizing operation, rendered precise at every step by explicit or implicit opposition, negation, or contrast. If, throughout the process of generalization, we avail ourselves of explicit contrast, to render precise both the particulars and the generalities, that one operation would be enough; defining would be generalizing pure and simple, and nothing besides. But there is often a great advantage gained by viewing, in a separate and distinct operation, the opposite or contrast of the thing defined; and hence we may lay down two canons, or two stages of the process—the first the canon of Generalization, the second, the canon of Contrast or Relativity; or, as Generalization must enter into both, we may call them the *Positive* and *Negative* Methods. Taken together they show that Defining is rendered thorough-going, first, by generalizing the Particulars of the Notion propounded, and secondly, by generalizing the Particulars of its Negative.

The method of Defining given in the ordinary works on Syllogistic Logic contains no reference to a generalizing operation. *The scholastic definition directs us to assign (1) a higher genus of the thing defined, and (2) the specific difference, or the distinction between the thing and the other species of the same genus (*per genus et differentiam*) No mention is made of the way of obtaining either the characters of the genus, or the differential characters of the species. Suppose we were to define Chemistry in this way; (genus) a Science, (differentia) having reference to a peculiar kind of Combination of Bodies, called chemical;—it is obvious that

to give such a definition we must scan the subjects ordinarily included in Chemistry, and, by generalizing them, find an expression suitable to them all, and to none besides. Hence, the direction to assign the genus and the difference, merely relates to the form of *expressing* the result of a generalizing operation.

Allusion is made, by Mr. Mill, to a mode of defining by 'Analysis,' or by resolving a complex notion into its constituent elementary notions; as when we define Eloquence—'the power of influencing men's conduct by means of speech.' Here, Eloquence is a complex property, resolved into the two simpler properties, 'exerting influence over men's conduct,' and 'speech.' If, however, the enquiry was made, how do we arrive at this definition, the only answer would be, by generalizing from the particular examples of eloquent address; so that, in point of fact, this method, if it be a method, does not supersede the processes of generalization.

The analytic statement could, if we please, be thrown into the scholastic form; we have merely to adopt one of the component notions as a 'genus,' and call the others 'differentia;' influencing of men's conduct (genus), use of speech (differentia). We might even reverse the notions; 'speech' (genus), 'for influencing human conduct' (differentia).

Thus, neither of these two modes of defining can come into competition with the main circumstance insisted on, namely, that to define is to generalize. On what occasions, the generalizing process may be dispensed with, will be a matter of future consideration.

Positive Method.

3. *Canon.* Assemble for comparison the Particulars coming under the Notion to be defined.

By the Particulars are meant, not every individual instance, but *representative* instances sufficient to embrace the extreme varieties.

To define a species of Plants, the botanist collects recognized examples of the species, including the widest extremes admitted into it. He compares the several specimens, noting their agreements, until he finds what characters pervade the whole; these he expresses in suitable language, which language is henceforth the definition of the species. So, in dealing with the higher groupings—genera, orders, and classes—he follows

the same obvious plan. Likewise, the zoologist and mineralogist have, in the last resort, no other method.

Further to elucidate defining by the generalization of the positive particulars, we will select examples such as to bring out the difficult situations, and will indicate, in the form of subordinate canons, the modes of overcoming the difficulties.

Suppose we have to define a *Monarchy*. We must begin by assembling instances of every institution that has ever been called by the name: the kings of the heroic age in Greece; the Spartan kings; the Roman kings; the Persian, Macedonian, Syrian, and Egyptian kings; the Teutonic king; the kings of modern European nations; the kings of the negro tribes; the emperors; the reigning dukes, margraves, counts, bishops, &c. To these we should have to add the king-archon at Athens, and the king of the sacrifices at Rome—mere relics of the ancient kingly government (Sir G. C. Lewis, Methods of Politics, I. 86). Now, if we confined ourselves to a certain number of these, we should find the common fact of absolute or despotic government; this, however, fails to apply to other instances, as our modern constitutional monarchies; and, if these are to be included, the common features are greatly reduced in significance, being, in fact, little more than (1) the highest dignity in the state, and (2) a participation, greater or less, in the sovereign authority. But again, if we look to the two last instances—the king-archon at Athens, and the king of the sacrifices at Rome—we shall not be able to apply to them even the attenuated community just given; there would be required a still farther attenuation, reducing the points of agreement to utter insignificance.

Now this is one of the most usual situations arising in the attempt to generalize a notion with a view to definition. We must be led in the first instance, by the popular denotation of the name; yet, if we abide by that, we fail to obtain any important community of meaning. It is in such a perplexity, that the golden rule must be called to our aid; we must take some means to form a class upon a deep and wide agreement. If need be, we must *depart from the received denotation;* leaving out some instances, and taking in others, until we form a class really possessing important class attributes. Thus, in the case of the monarch, we should cut off at once the mere relics of old kingly power. As regards the rest, we should divide the instances between the absolute and the limited monarchies; there is a large and important community

of meaning in the class termed 'absolute monarchies,' and this class should be isolated, and should make a distinct notion in political science. The remaining individuals should be dealt with apart; they (as shown by Sir G. C. Lewis) are far better excluded from Monarchies, and classed with Republics. 'By including in monarchies, and excluding from republics, every government of which a king is the head, *we make every true general proposition respecting monarchies and republics impossible.*' In this state of things an operation of *re-classing* is the indispensable scientific corrective of the popular and received generalities.

The definition of a *Colony* would afford a case exactly parallel. Taking together all the things that have ever borne this name in ancient or in modern times—the colonies of the Phenicians, Greeks, Romans, Italians, Spaniards, Portugese, Dutch, French, English—we should find these facts in common, namely, emigrating from the mother country, settling in some new spot, and displacing the previous government, if not also the population, of the place occupied. With this small amount of agreement, there are very wide disparities, and until we narrow the instances, we do not arrive at a large and important connotation or meaning. If, however, discarding the ancient colonies, we make the comparison among the modern instances, we find the important circumstance of a sustained political relationship with the mother country; which is better expressed by the word *dependency*. And by sub-dividing the class, we can obtain inferior classes, with still more numerous important points of agreement; as, for example, the Canadian and Australian colonies of this country, which exercise the powers of independent legislation, under the least possible control by the home government.

Let us next endeavour to define *Food*. According to the canon, we assemble representative examples of all the substances ever recognized under this name. We have before us, the flesh of animals, the esculent roots, fruits, leaves, &c. We have also a number of substances of purely mineral origin, as water and common salt. Our work lies in generalizing these, in detecting community in the midst of much difference. Were man a purely carnivorous feeder, his food might be generalized as the flesh of animals taken into the mouth, and passed into the stomach, to be there digested and thence to be applied to the nutrition and support of the system. But when we include vegetable and mineral bodies, we must leave out 'flesh,' and substitute 'animal, vegetable, and mineral

substances;' the other part of the statement being applicable. Even as amended, however, the definition is still tentative, and needs to be verified by comparison in detail with everything that has ever been put forward as food. We must challenge all informed critics to say where the definition fails. Thus, nourishment is afforded by substances absorbed through the skin, which would exclude the medium of the mouth and stomach, and narrow the definition to nourishing or supporting the system. Again, it is doubted, whether alcohol, tea, tobacco (chewed) really nourish the system. This is a far more serious objection; and the manner of dealing with it will illustrate the principles of defining.

In the first place, there may be a contest as to the matter of fact. Could it be shown that these substances do give nourishment, support, or strength to the system, the difficulty is at once overcome; in that case, they fall under the definition. On the contrary supposition—that they do not nourish the the system,—two courses are open. First, we may exclude them from the class 'Food,' and retain the definition. Or secondly, we may include them, and alter the definition. As modified to suit the extension, the definition would be 'substances that either nourish or stimulate the system.' To decide between those two courses, we must, as before, refer to the golden rule of classification, which recommends the adherence to a smaller class founded on a great and important community, rather than to a larger where the community of meaning is attenuated to comparative insignificance. Better, therefore, to retain two groups—Foods and Stimulants,—each with its own definition. In that way, we should derive much more information respecting any individual thing designated either 'Food' or 'Stimulant,' than if the word 'food' covered both. It may be that some substances combine both functions; which would entitle them to be named in both classes.

We may notice the definition formerly given of 'Axiom' by way of remarking that a definition is obviously spurious that does not distinguish the given notion from notions already settled. Thus, unless an Axiom be a real proposition, it is not divided from Definitions; and unless it is fundamental within the science, it does not differ from the great body of Propositions so far as employed to prove other propositions. The characters proposed are alone sufficient to constitute a separate notion bearing the name.

These cases sufficiently exemplify the situation where a

word is extended to denote things that have few or no important points of community. The next example will bring to view a perplexity of another kind.

Suppose we seek to define a *Solid*. Summoning to view, if not all the solids in nature, sufficient representatives of all the varieties compatible with the name—metals, rocks, woods, bones, and all the products of vegetable and animal life denominated solid—we set to work to compare them, and note their agreement. There is little apparent difficulty in this instance. We see that, however various these bodies may be, they agree in resisting force applied to change their form; so readily does this strike us at first sight, that the case seems scarcely worth producing to exemplify a logical formula. Let us, however, apply the Socratic test—exposing the definition to the cavil of every objector,—and we shall probably soon be told of a grave difficulty. The quality, so very decided in the great mass of instances, is found to have degrees, to shade insensibly into the state called 'liquid,' where solidity terminates. Now, at what point does solidity end, and the opposite state begin? Is a paste, a glue, a jelly, solid or not? Is Hamlet right in talking of 'this too, too solid *flesh*?'

We have here not a mere cavil, but a frequent and serious perplexity. Many couples of qualities, unmistakeably contrasted in the greater number of instances of them, pass into one another by insensible gradations, rendering impossible the drawing of a hard and fast line. Who shall say at what moment day ends and night begins? So, there has always been a doubt as to the exact individual that ends the animal series, and is neighbour to the beginning of the plant series. Sleeping and waking may have an intermediate state, with difficulty assigned to either. The great chemical sub-division into metals and non-metals has an ambiguous border in the substances arsenic and tellurium. In the animal system, the voluntary shades insensibly into the involuntary.

The Greek philosophers displayed to the utmost the ingenuity that lights upon difficulties; and this example did not escape them. They grounded upon it a puzzle named the *Sorites*, or heap. A certain heap was presented, which was fairly designated small; it was then increased by very gradual additions; and the spectator was challenged to declare at what point it ceased to be small, and deserved to be accounted large.

There is but one solution of the riddle. A certain *margin*

must be allowed as *undetermined*, and as open to difference of opinion; and such a margin of ambiguity is not to be held as invalidating the radical contrast of qualities on either side. No one would enter into a dispute as to the moment when day passed into night; nor would the uncertainty as to this moment be admitted as a reason for confounding day and night. We must agree to differ upon the instants of transition in all such cases. While the great body of the non-metals can be distinctly marked off from the metals, we refrain from positively maintaining arsenic and tellurium to be of either class; they are transition individuals, the 'frontier' instances of Bacon; in that position we leave them.

There is a margin of transition in the ethical distinction of Reward and Punishment. In the great part of their extent, these two motives are amply contrasted; to bestow a reward for performance, is a different thing from inflicting punishment for non-performance; and the withholding of a reward is not confounded with punishment Yet circumstances arise when the one merges into the other. A kind parent withholds from a child some indulgence originally meant as a reward; if the indulgence has been so frequent as to become a kind of use and wont, the privation is hardly distinguishable from punishment.

When it is said, no man is to be punished for his opinions, we are not to infer that each person is bound to associate alike with all persons of all opinions, because to give a preference is to stigmatize some at the expense of others. Our not choosing any one as a companion and friend is not to be held as inflicting a penalty, or as manifesting disapprobation.

We may farther exemplify the method upon *Matter*. Assembling the various things recognized as material, say solid and liquid bodies, and comparing them among themselves, we find a unanimity in these points, namely, resistance to motion or force applied to them, and exercising power or force when in motion. All solids and all liquids agree in these features. They farther agree in being visible and tangible. We must next bring into comparison the gaseous bodies. Do these possess the same quality as to resistance and moving power? The identity is not at first sight apparent, but becomes so on a closer inspection; airs resist motion, and constitute moving power, although in a comparatively less degree than solids and liquids. They are not, however, as a class, visible and tangible; consequently, either these qualities must be dropt, or gaseous bodies must be excluded; we must make our

choice. The decision is not difficult. So exceedingly important is the material property of Resistance and Momentum (given in one word—Inertia), that we are justified in making it the foundation of a class, even although we associate together things visible and tangible, and things invisible and intangible.

The next enquiry relates to the Ether, or etherial medium, occupying all space. Shall this be included in the class 'Matter?' If the property of Inertness can be proved to belong to the supposed Ether, we must include it. On the contrary supposition, we are in the alternative position already exemplified; we must either exclude the instance or attenuate the defining properties. Now, the only community that could exist between an unresisting Ether and Matter would be this very general circumstance, namely, being an extended medium for the operation of forces. The supposed ether conveys light and heat, and is therefore a transitory embodiment of molecular force, as solids, liquids, and gases, are of force, both molar and molecular. Better, however, on this extreme supposition, not to class the Ether with Matter, but to leave, as the defining property of Matter, the all-important fact described by Inertia.

The foregoing instances under the Positive Canon are enough to show Definition in its primary character as a generalizing operation, and also to bring out the leading difficulties of the process—the adjustment of the particulars to comply with the golden precept, and the allowance of a doubtful margin in cases where opposites pass insensibly into each other.

Negative Method.

4. *Canon.*—Assemble for comparison the particulars of the Opposed, or contrasting Notion.

This amounts to saying that, with the given Notion, we shall also define, by the same generalizing method, the opposing Notion. As it is impossible for anything to be precisely defined, unless its opposite is known, and defined with equal precision, we must in substance perform the two-fold operation, whether or not we formally separate the opposing aspects. The cases where the formal separation is expedient will be made manifest by a few examples.

It is impossible to place the human mind in a more favourable position for comprehending a generality, than by laying

out to the view two arrays of particulars—the one representing the given notion, the other its negative. The notion of Straightness, for example, is thoroughly set forth by placing a series of straight objects (of all varieties in other properties) side by side with a series of bent, curved, or crooked objects. Supposing the representation of both sides to be complete, the very utmost has been done to put the learner in possession of the notion, idea, or concept, called 'straight.'

Let us apply the method to the definition of a *Solid*. The positive generalization leads to the expression of the common attribute thus:—'Solids resist force applied to change their form.' Try next the negative plan, by generalizing liquids (and gases). On an adequate comparison of these non-solids, we are able to say, 'liquids and gases yield to the slightest pressure, and have no fixed form, except as given by solid enclosures;' which is the exact obverse, and, therefore, the confirmation of the prior statement with reference to solids.

Reverting now to the definition of Matter, already worked out on the positive side, let us seek for a negative generalization. But what is the negative of Matter? Most persons would answer 'Mind;' which is true, but not the whole truth. Matter is indeed opposed to Mind; but it is also opposed to Space unoccupied (except by the supposed Ether). The complete opposition to Mind is *Extension*, whether as resisting Matter or unresisting Space. We have therefore to oppose Matter to *Space*, and ask the definition of Space. Now, on comparing all our experiences of what we term empty or unoccupied space, we find this common fact, *freedom to move*, or scope for movement; a definition the exact obverse of the definition of matter, or of the fact called Resistance or Inertness.

Matter is sometimes opposed to Force. An argument for the immateriality of mind is founded on this opposition. Thus Hartley says, matter which is inert, cannot be the substance of mind, which is active, or a source of power. This is a pure mistake and confusion of ideas. It takes up one aspect of Matter—resistance, and drops the other aspect—moving force. The two aspects are inseparable; force is moving matter; without matter there is no force.

The method of Opposites will be seen to advantage in defining *Chemical Combination*, the subject matter of the science of Chemistry. By the positive canon, we have to assemble numerous instances of the so-called Chemical unions—the union of oxygen and hydrogen to form water, oxygen and

carbon in carbonic acid, &c. The operation would turn out a very laborious one, from the great multitude of the particulars to be examined even for adequacy of representation. We shall, however, suppose that there has been obtained a general statement of the points of community; namely, change of properties, definite proportions, and heat.

We next ask what is Chemical Combination opposed to? Of the *genus*—Combination, what are the *species* not chemical? The answer is Mechanical mixture and Solution (in its broad phase of molecular adhesion). We should then have to generalize these two, and confront the points of agreement with those above given. Now, we may dispense with drawing a formal contrast between Chemical union and Mechanical mixture; for this reason, that the two are so prominently distinct as not to be in danger of being confounded. The profitable contrast is with Solution. Generalizing the instances of solvent attraction—in common solutions, in alloys, &c.,—we see that although the solidity of a body may be broken up, or its state changed, it retains the greater number of its characteristic properties; salt and sugar, when dissolved, are the same for most purposes; the change is comparatively insignificant. Again, solution may be in all degrees up to saturation. Finally, solution is usually a cooling operation. These are the precise opposites of Chemical union. We may draw up a pointedly contrasting definition in this form:—

COMBINATION	SOLUTION
Characters of the Compounds	
Merged	Retained
Proportion of Combining	
Definite	Indefinite
Resulting change of Temperature	
Heat	Cold.

In the above instance, the Negative generalization is the easier of the two; the field of instances being sooner overtaken. The same advantage belongs to the defining of *Mind* by the opposite. The particulars constituting Mind are numerous, various, and complicated; the particulars constituting *Extension*, the property opposed to mind, are much sooner gathered up into a general notion, and that notion is much more distinct and familiar than the properties of mind: moreover, the community of Extension is single; of mind, plural.

Opposing notions, having between them a border of ambiguous instances, are best cleared up by the method of Negation,

with pointed contrast. We formerly had to notice the subtlety of the line that, on some occasions, divides the Notion from the Proposition; the definition of a complex notion being often very difficult to distinguish from a Proposition.

Appetite is not sufficiently defined unless pointedly opposed to the notion most nearly allied with it—Desire.

The principle of *Utility*, as the moral standard, is opposed by Bentham, to the two principles—Asceticism, and Sympathy or Antipathy (Sentiment).

The *Plant* or *Vegetable* is defined by a parallel array of contrasts with the Animal; and conversely.

Deductive Definitions

5. When Complex Notions are formed by compounding simpler notions, as in the Deductive Sciences, they may be defined by stating their composition.

In the Deductive Sciences, as Mathematics, notions as well as propositions are formed by artificial composition or deduction. Given the notion 'triangle,' and the various notions 'right angle,' 'equality,' &c., we can construct the complex notions 'right-angled triangle,' equilateral triangle,' 'isosceles triangle.' No reference to particulars is needed for defining such notions; we merely recite the elements used in compounding them; 'a right-angled triangle is a triangle with one right angle.'

Having the notion 'attractive force,' and the various numerical notions, squares, cubes, &c., we constitute the artificial compounds, 'force as the square of the distance, the cube of the distance,' and so on.

This is the one grand exception to the principle of defining by the generalization of Particulars. From the magnitude of our Deductive Sciences, there is a very large number of such notions; and they have been the means of withdrawing attention from the fundamental process of Defining through the comparison of instances in the concrete.

We make artificial compounds, not merely for scientific ends, as in the Deductive Sciences, but also in the exercise of Imagination, as when we feign gods, demi-gods, demons, dragons, and ideal personages and scenes in poetry. The definition of these notions also is the statement of their composition.

The Language of Definition.

6. The Language of Definition consists in assigning the *constituents* of a Complex Notion.

The dictionary definitions by *synonyms* have an incidental value, but are not proper definitions.

The generalizing operation terminates in the seizing of common features, which have to be embodied in language. Now, the language used must express some more elementary notions, whose combination gives the required notion. 'A solid resists force applied to change its form'—is an expression substituting for the word 'solid' a coalition of more elementary and general names—'resistance,' 'force,' 'change,' 'form.' The definition of Property is—'the right of each person to dispose of whatever things of value they have either acquired by their own labour, or obtained by free gift or by fair agreement from those that have so acquired it.' Here the constituent notions are 'right,' 'disposal,' 'value,' 'acquisition,' 'labour,' 'gift,' 'agreement.'

Liberty is definable as the power of using one's faculties at will, subject (if Civil Liberty be meant) to not interfering with the like use in others; implicating 'power,' 'faculties,' 'will.'

Thus the so-called method of 'Analysis' is the method of *expressing* every proper Definition. Whether the source of the definition be the generalization of particulars, or whether it be deductive as just explained, the wording of it is analytic.

The use of synonyms in defining depends upon the circumstance that almost every notion or thing has a plurality of names, and may be better known by some of these than by others. There are many names for the fact called 'pleasure:' joy, enjoyment, delight, happiness, felicity, delectation, rapture, ecstacy. The less familiar of these names are explained by the help of the more familiar; but this is not scientific defining.

7. The scholastic formula of defining—*per genus et differentiam*—like Analysis, belongs to the expression, rather than to the discovery of the meaning of a notion.

Each of the constituent notions expressing a complex notion is necessarily more general than the compound. 'Three,' 'side,' and 'figure' are each more general than the notion 'triangle,' which they express by their combination. We may, therefore, take any one of these and call it generic or the *genus*—say 'figure:' 'triangle' is then a species of figure; and its *differentia* or specific marks discriminating it from other figures are given in the remaining characters 'three' and 'side,' combined into 'three-sided.' So, if eloquence be

defined, analytically, as 'the influencing of men's feelings and conduct by means of speech,' we might call 'influencing men's conduct,' the genus, and 'the employment of speech,' the specific difference. We might, also, invert the terms and make 'speech' the genus, and 'influencing men' the difference.

This latitude, however, is usually restrained by the circumstance that one of the constituent properties is the basis of a recognized class, already existing. Thus, in defining a circle, 'line' is the recognized genus, and 'equal distance from a point,' the specifying attribute. A great number of classes and class notions fall under some superior class, or notion, on some one or more of their attributes. Not to mention the systematic classifications of Natural History, we may point to such cases as Painting (genus Fine Art), Mathematics (genus Science), Prudence (genus Virtue), Planet (genus Heavenly Body), Gold (genus Metal), Whiteness (genus Colour), Cathedral (genus Building).

Instead of presenting an exhaustive analysis of a notion, or class connotation, this method supposes that generic properties are already known, that people are, as it were, educated up to the point of comprehending the genus, and need only to have the genus mentioned, and the specific differences stated. Thus Mathematics is the Science (genus) of quantity (difference). Ethics is the Science (genus) of men's duties (difference). Painting is the Fine Art (genus) that works by colour (difference). Poetry is a Fine Art employing the instrument of language. Prudence is a Virtue (genus) having reference to the welfare of the individual agent (difference). Justice is a Virtue, involving an equal and impartial distribution of advantages, according to a received scale or standard. Politeness is Benevolence in trifles. Religion is Government (genus) by a Supernatural power (difference). Wonder, Fear, Love, Anger, are of the genus 'Emotion,' each having a specific difference. Sight is of the genus 'Sensation;' difference, 'by the Eye.'

Locke's remarks on the scholastic type are very much in point. They are in substance these:—When, in defining, we make use of the genus, or next general word, it is not out of necessity, but only to save the labour of enumerating the several simple ideas that such general word already expresses, (or perhaps the shame of not being able to give the full enumeration). Definition being nothing but making any one understand by words what idea the given word stands for, it is best made by giving all the simple ideas combined in the signification of the term; and if people

have been accustomed, instead of the full enumeration, to use the next general term, it is neither from necessity nor for greater clearness, but for quickness and despatch. (Essay. Book III. Chap. II.)

Ultimate Notions.

8. For simple or Ultimate Notions, the generalization from Particulars still holds, but verbal expression necessarily fails.

For attaining the notion 'whiteness' we gather particular examples of white colour, and of colours not-white. The conjunct impression of the positive and the negative particulars does everything that can be done to master or to convey the notion; we may then attach a name to enable it to be spoken upon, but we cannot give a verbal definition of it; there are no notions, more elementary, whose combination would give the notion 'white.' So we cannot by any form of words convey the idea of 'resisting;' as an ultimate fact it can be known only in the actual experience of a comparison of resisting things.

We may define Equality by Coincidence, but we can give no definition of Coincidence, we must show it. Any attempt at verbal expression, by such synomyms as 'agreeing in size,' 'exactly fitting,' would be illusory.

Succession and Co-existence are an ultimate contrasted couple, definable only by reference to examples.

Unity and its opposite, Plurality, are indefinable. We must produce an array of objects with the common attribute, singleness, and another array of groups, and the comparison of the two arrays by the observer is the only possible mode of attaining the conception.

A Mathematical point is indefinable. The definition given in books in geometry, 'position without magnitude' is not more elementary but more complex, than the thing defined. The correct mode of defining a point for geometrical purposes seems to be to indicate to the eye positions or landmarks where we begin or end a measurement, or make a division. The knowledge of a point or a position is obtained in the same concrete examination that gives length and space dimensions.

A line is not definable; as just noticed, it is an abstraction derived from comparing extended bodies.

An angle is not definable; 'inclination' is merely another name for the entire notion, it is not a simpler or more elementary conception. Actual examples must be shown. There is a mutual implication of a circle with an angle, so that if we

were made to master a circle in the first instance, we might then learn an angle by definition; but in the process of knowing the circle we conld not avoid knowing an angle.*

'Complex ideas,' says Hume, 'may, perhaps be well known by definition, which is nothing but an enumeration of those parts or

* Our sensibilities in general give us the experiences of Difference and Agreement; Quantity, amount or degree, Number, or discrete quantity; and Time (Succession is not fully given until we have the special experience of the simultaneous, an acquired and complex notion).

The Muscular sensibilities, in particular, give Resistance and Motion; which, by the farther help of sense experiences, are unfolded into Space and Co-existence.

Every one of the Senses contains one or more ultimate experiences, no one sense can enable us to conceive what belongs to another. What number of independent or underivable sensations should be attributed to each sense, we cannot easily say; whiteness, and the simple colours must be conceived as ultimate; while even the compounds and shades of colour are probably for the most part beyond our power to conceive by any mere coustructive effort, or apart from actual experience, a circumstance that would make the ultimate notions of sight very numerous. Similar remarks may be extended to Sounds, Touches, Smells, and Tastes; under every one of these classes of sensations, there must be a considerable number that cannot be referred by derivation to others, and must be separately experienced. Our Organic Sensibilities, in like manner, contain numerous characteristic and independent modes; hunger, thirst, repletion, suffocation, headache, rheumatism, &c., are all indefinable by analysis, because they are ultimate modes of sensibility. Even although many of them have a common character, pain, they have a speciality which can be understood only by being felt.

In the higher Emotions, as Wonder, Fear, Love, Anger, Pride, Curiosity, we have many compound states. The æsthetic pleasures are a combination of simpler modes. Still, a certain number of emotions are to appearance ultimate, as Wonder, Fear, Tenderness, Power, while there is an absolute certainty that they could not be conceived without being actually felt. Moreover, many emotions that the Psychologist is able to analyze could yet be constructed only with very great difficulty by the help of the elements alone. A person that never experienced the sentiment of veneration could scarcely arrive at it by merely being told what are its constituents.

The elementary experiences of the mind are, therefore, very numerous, and so, therefore, are the indefinable notions. The varied situations of human life give birth to notions practically indefinable; the idea of a Political Society could not be communicated to any one that had never been a member of some actual society. Hence, in our attempts to define Government, Law, Authority, we must make an appeal to the concrete experiences of the listener.

When all such cases are taken into account, the notions that are of an indefinable and ultimate nature must be reckoned by hundreds. Dictionary makers have hitherto overlooked this circumstance; and hence their pretended definitions revolve in a circle of words, where there should be a reference to actual things. How vain is a verbal definition of such words as light, heat, motion, large, up, fragrance, pain, wonder!

simple ideas, that compose them. But when we have pushed up definitions to the most simple ideas, and find still some ambiguity and obscurity; what resource are we then possessed of? By what invention can we throw light upon these ideas, and render them altogether precise and determinate to our intellectual view? Produce the impressions or original sentiments, from which the ideas are copied.'

Locke considers himself to have been the first to remark that Simple Ideas are indefinable. By Reid and by Stewart, the merit of first stating the fact is ascribed to Descartes. Hamilton would trace it back to Aristotle (Reid's Works, p. 220): but Mr. Mansel questions the interpretation put by Hamilton upon the passage apparently relied on (Aldrich, Appendix, Definition), and quotes a remarkable passage from Occam, approaching closely to Locke's position concerning Simple Ideas. Aristotle, says Mansel, may be cited as an authority for limiting the indefinable to Summa Genera and to Individuals.

Aristotle's general theory of Definition is much perplexed by being treated as an investigation of Cause, and by keeping up the distinction of Substance and Attribute. But, in regard to 'hunting for,' as he expressed the search after, a definition, he allows the method of generalization from particulars, as well as the deductive method, by working down from a higher genus. He also gives an intelligible distinction between Nominal and Real Defining. The Nominal definition applies 'where there is no evidence of the existence of the objects,' as when we define a purely imaginary being, such as a centaur. This of course could only be a deductive definition. Real definition applies to things known to exist and would be most completely exemplified in defining by a generalization of particulars.

Mr. Mill draws the line between Nominal and Real Definitions —Definitions of Names and Definitions of Things—by remarking that the last-named kind, along with the meaning of a term, covertly asserts a matter of fact. (Book I., Chap. VIII.). The Real Definition postulates the *real existence* of the thing defined. In another place, however (Book III., Chap. V.), while discussing the hypothetical character of the Definitions of Geometry, Mr. Mill remarks truly that in order to reason out facts we must shape our hypotheses to facts; imaginary assumptions could bear imaginary consequences, but we need real assumptions in order to give real consequences.

CHAPTER II.

GENERAL NAMES.

1. General Names may not be absolutely indispensable to general notions, but, besides being necessary to communication, they aid the memory in remembering generalities, while without them, we could not combine a number of distinct notions into propositions and reasonings.

We might discover similarities in nature, and might remember and act upon such discoveries, without the use of language. We could not, however, impart such discoveries to others. We might, indeed, in some instances, put the resembling things side by side, which would make the identifying operation somewhat easier to those that came after us. By a similar device, we might indicate a natural conjunction, in certain very limited circumstances. The powers of fire might be expressed by putting on one side of a fire, a pile of wood, and on the other a heap of ashes; even this would not be intelligible without pantomime. But beyond the simplest cases, the attempt at expressing general laws would utterly break down.

Our own recollection of discoveries of identity is vastly lightened by the use of names. The employment of the same name to the resembling things, both expresses the things as individuals and declares their community or likeness; this mode of signifying likeness being of all others the least burdensome to the memory. The complex and many-sided likeness in difference, characteristic of natural objects — the possibility of including the same object, an orange for example, in a great number of classes—renders this easy mode of keeping the various communities before the mind, of inestimable value. By the use of a few terms—round, yellow, soft, sweet, we can compendiously grasp all the relationships of the orange, and make them enter into our reasonings with comparative ease. No discovery of identity among objects is secured against neglect, until, joined to a common name, it can be borne in men's minds by means of this gentle and constant insinuation.

2. The conditions of general Naming fall under two heads.

First. Every name should have a meaning well defined.

The necessity of this is too obvious to need enforcement. Every science should have all its terms defined. The end of the Logic of Definition is to fix the meanings of general names.

We find in point of fact that words often possess numerous, distracting, and incompatible meanings. Take the familiar term 'stone.' It is applied to mineral and rocky materials, to the kernels of fruit, to the accumulations in the gall bladder, and in the kidney; while it is refused to polished minerals (called gems), to rocks that have the cleavage suited for roofing (slates), and to baked clay (bricks). It occurs in the designation of the magnetic oxide of iron (loadstone), and not in speaking of other metallic ores. Such a term is wholly unfit for accurate reasoning, unless hedged round on every occasion by other phrases; as building stone, precious stone, gall stone, &c. Moreover, the methods of definition are baffled for want of sufficient community to ground upon. There is no quality uniformly present in the cases where it is applied, and uniformly absent where it is not applied; hence, the definer would have to employ largely the licence of striking off existing applications and taking in new ones.

§ 3. The demand for new names is a cause of the loose extension of words already in use. The processes of extension are Similarity, Composition, and Contiguity.

(1) The operation by Similarity is described by the name. A new object is brought into comparison with some one already known, and the name transferred accordingly. Thus, on the discovery of an additional coal-field, all the designations previously in use in connexion with coal are legitimately extended to the new formation. More precarious extensions by similarity are often made It is enough to mention the whole class of metaphors, wherein, by virtue of similarity, accompanied by serious diversities, old words are employed in new meanings — 'light' to signify knowledge, 'fire' to denote zeal and irascibility, 'birth' and 'death' to mean many things differing widely from the beginning and the ending of life in an organized being.

(2) The process of Composition is shown in framing new words, by the union of existing words; as log-book, mince-meat, hail-stones, far-sighted, and by the systematic employment of prefixes and suffixes, prejudge, undo, withhold, boundless, wisdom, bearer, unnecessary.

The same process is seen in using a plurality of words to convey a single meaning: as in the systematic designation by genus and species, white man, moss rose; and in numerous many-worded combinations and circumlocutions — 'the last surviving descendant of an ancient family,' 'the father of History.'

(3) The process of Contiguity is exemplified in the figure called Metonymy—as in using the 'crown' for royalty, the 'turf' for horse-racing. So long as the figurative character of this operation is kept in view, there is no harm done. A more dangerous employment of contiguity is exemplified in what is termed the 'Transitive application of words.' This operation demands special notice.

4. A word originally applied to a thing, by virtue of one quality, may contract the additional meaning of some associated quality, and thence be extended to things possessing the second quality singly.

This tendency was brought into prominence by Dugald Stewart, who gives the following symbolical elucidation of it. 'Suppose that the letters A, B, C, D, E, denote a series of objects; that A possesses some one quality in common with B; B a quality in common with C; C a quality in common with D; D a quality in common with E; while at the same time, no quality can be found which belongs in common to any *three* objects in the series. Is it not conceivable, that the affinity between A and B may produce a transference of the name of the first to the second; and that, in consequence of the other affinities which connect the remaining objects together, the same name may pass in succession from B to C; from C to D; and from D to E?'

The word 'damp' primarily signified moist, humid, wet. But the property is often accompanied with the feeling of cold or chilness, and hence the idea of cold is strongly suggested by the word. This is not all. Proceeding upon the superadded meaning, we speak of damping a man's ardour, a metaphor where the cooling is the only circumstance concerned; we go on still farther to designate the iron slide that shuts off the draft of a stove, 'the damper,' the primary meaning being now entirely dropt. 'Dry' in like manner, through signifying the absence of moisture, water, or liquidity is applied to sulphuric acid containing no water, although not thereby ceasing to be a moist, wet, or liquid substance.

The word 'letter' has undergone a series of transitions. Originally applied to the alphabetic characters, it passed to epistolary correspondence, to literature (letters); but in our post-office system it has strayed still wider; it has come to mean parcels made up of jewellery, soft goods, and miscellaneous wares, provided they are carried by post.

'Gas' is the popular name for any effluvia, anything in the air. Cloud and smoke would be called gaseous emanations, although they are not properly aerial bodies.

A 'back door' originally the door at the back of the house, for servants, is applied to the door for the same purpose when in front of the house.

'Street,' originally a paved way, with or without houses, has been extended to roads lined with houses, whether paved or unpaved.

'Impertinent' signified at first irrelevant, alien to the purpose in hand; through which it has come to mean, meddling, intrusive, unmannerly, insolent. So wide is the difference between the first and last senses, that, in spite of the apparent ease of the transitions, Mr. Bailey suspects the influence of the similarity in sound with the epithet 'pert' (Discourses, p. 101).

'Taste' is transferred by similarity, or metaphor, from the feelings of the sense of Taste, to the feelings of Fine Art productions. There is also, in all probability, a transition in the double meaning of the word in both employments, namely, to signify the *pleasure* imparted, and also the *discrimination* of bodies by taste, and of good and bad in Fine Art productions.

Examples may be quoted from the highest questions of philosophy. Thus, the epithet 'beautiful,' properly circumscribed by Fine Art, is often loosely applied to pleasures not artistic.

This misleading tendency was never adverted to by either Plato or Aristotle, who, in their enquries, counted on finding under such words as Beauty, Cause, Justice, some unity of signification. The same mistake pervades Bacon's inductive enquiries.

The word 'gentleman' is an example of transitions growing out of historical and political circumstances. 'Meaning originally a man born in a certain rank, it came by degrees to connote all such qualities or adventitious circumstances as were usually found to belong to persons of that rank. This consideration explains why in one of its vulgar acceptations it means any one who lived without labour, in another without

manual labour, and in its more elevated signification it has in every age signified the conduct, character, habits and outward appearance, in whomsoever found, which, according to the ideas of that age, belonged or were expected to belong to persons born and educated in a high social position.'

Similar changes are traceable in the words 'loyalty,' 'villain,' 'pagan.'

A 'convict' properly means one convicted or found guilty; but the signification most prominent is the transition to the state of hard labour entering into the punishment of convicted felons.

5. The derivations of terms frequently exhibit, in conjunction with contiguous transitions, an element of similarity.

In an interesting chapter devoted by Mr. Mill to 'the Natural History of the Variation of the meaning of terms,' he notes two different tendencies to change both grounded in similarity—the one a movement of Generalization, the other a movement of Specialization.

As to the first, the rendering of specific terms general, we have such examples as 'salt' extended from sea salt, to the class of saline bodies; 'oil' from olive oils to oils generally; 'squire' from the owner of a landed estate to other classes supposed to be entitled to a similar position; 'parson' from the incumbent of a parish to clergymen at large.

The Specialization of terms is apt to arise when people have occasion to think and speak oftener of one member of the genus than of the others. Thus 'Magazine,' a store or receptacle, has been narrowed to a periodical publication. 'Cake' is specialized to pastry. A 'story' is used to designate a lie—a curious illustration of the frequent inaccuracy of current narratives. 'Pleasure' has oftener the signification of a very narrow class of enjoyments; to which corresponds a special meaning of 'virtue' and virtuous. 'Wit' formerly meant intellectual power of any kind; Bacon, Milton, and Newton were great wits. The modern tendency is to restrict it to the production of ludicrous effects, and even still farther to the ingenious play upon words.

6. The precautions to be observed in re-adjusting the signification of terms, are these:—First, important meanings in current use, or meanings at the base of important predications, should not be disturbed, secondly, the associations of powerful sentiment should not be reversed.

In restricting the word 'beauty' to the refined pleasures of Art, and of the artistic element of Nature, we do not interfere with any received propositions, nor with the approving sentiment, connected with the term. The word 'wit,' in its modern restriction, has undergone a much greater revolution, and certainly does not support the same propositions, nor the same associations of dignity as in Queen Anne's time. 'Justice' cannot be accurately defined without a reference, in the last resort, to law, authority, or command; or at least to men's opinions as to what should be authoritatively enjoined or commanded; a mode of defining that has always been unpalatable, as making the illustrious quality of Justice, the creature of law and opinion.

'Civilization' should, if possible, be so defined that the European nations should be included, and the American Indians, Bosjesmans, and aboriginal Australians excluded; while no unfavourable sentiment should be introduced, by giving preponderance (as Rousseau did) to the supposed evils, or disadvantages, attending on the arts and discoveries of civilized nations.

The difficulties attending the re-definition of a word are illustrated by the repugnance felt by many to Mr. Grote's view of the sophists; a view that conflicted both with prevailing propositions and with feelings of dislike. A regard to truth or to justice may necessitate our violently interfering with a received usage.

From the strong tendency to associate the word 'pleasure' with the gratifications that border on vice, ethical theorists are hampered in using it to express the natural and legitimate end of human pursuit. They have to substitute for it, happiness, well-being, or other words of more feeble import as regards the zest and enjoyment of life.

Mr. Mill adverts to cases where he thinks it might be a great misfortune to banish entirely the former meanings of words; inasmuch as the operation may involve the unfair predominance of a one-sided theory on some important questions. He supposes the temporary prevalence of a selfish theory of virtue, the consequence of which might be that the word 'virtue' would cease to connote disinterested conduct, and the very idea of such being dropt, the practice might degenerate accordingly. The remark, however, has no application to the words of obsolete physical theories, as 'epicycle,' 'phlogiston,' '*vis viva*,' or to names that distort and confuse the phenomena expressed by them, as free-will and necessity, or

to the names of infelicitous classifications, superseded by better. And in those changes of meaning adapted to the progress of science, as with the words salt, acid, it is expedient to drop entirely the earlier significations.

7. The second Requisite of language is, that there should be no important meaning without its word.

This involves (I.) a *Descriptive Terminology*.

It is essential that we should be able to describe with accuracy all individual facts and observations; consequently names must be devised for all the known qualities of things whether physical or mental, and also modes of signifying differences of degree whenever degree is taken into account. To describe the diamond, we need such names as crystal, refracting power, specific gravity, hardness; and a numerical scale for stating the amount or degree of each property. Separate names are required for all our ultimate feelings and sensations.

As regards the Object World, the fundamental experiences are the muscular states called Resistance and Motion, and the Sensations—which, in the order of their objectivity, are Sight, Touch, Hearing, Taste, Smell, Organic Sensations.

The property called *Resistance* has other names; as Force, Inertia, Momentum. Gravity is a mode of the same property. The only farther requisite is a scale of Degree, which, in this instance, is given by the one perfect method—Arithmetical numbers.

On the experience of movement, aided by sense, is grounded the object property called *Motion*, in all its varieties; also Space, Extension or Magnitude, and Form. The varieties of motion are quick and slow, regular and irregular, of this or that form, and so on. Names are given to all the modes, and for most, there are numerical estimates of degree. The same remarks apply to Space or Magnitude, which is pre-eminently open to arithmetical statement.

Form is a property subject to great variations, and names have to be found accordingly. The simple forms of Geometry—as line, straight, angular, curved, circle, triangle, sphere, cone, &c., are one department. The objects of nature and art have many others besides—heart-shaped, egg-shaped, pear-shaped.

The language of Botany is most exigent of designations of form.

Colour has been expressed by assuming a certain number of primary colours, and treating the rest as shades of these.

Thus, we have many different greens, blues, reds, yellows, greys; often characterized in the manner above described by quoting objects that exemplify them, sky blue, ultra-marine blue, apple green, blood red, French grey. These names, however, do not *define* the colours; they do not from two simple ideas enable us to conceive a compound without reference to the actual thing, they merely mark a species as distinct from other species.

To make colour as far as possible a precise character in Mineralogy, there is a classified list, introduced by Werner, giving a name to every important variety of mineral colour. Eight colours are chosen as fundamental, white, grey, black, blue, green, yellow, red, and brown, and under each of these is arrayed a list of shades. Thus, under 'blue' are enumerated,—blackish-blue, azure-blue, violet-blue, lavender-blue, plum-blue, berlin-blue, malt-blue, duck-blue, indigo-blue, sky-blue; ten varieties. Similarly for the others; the number of shades being in some cases greater, in others less.

For the scientific description of the outer or object world. the most essential properties are Magnitude, Form, Movement, Resistance (including all the modes of Force), and Colour. Next to these in importance are *Sounds*, which also posess a terminology. The musical notes can be given numerically and symbolically; all other varieties of sounds must be designated by distinct names, as melodious, harmonious, silvery, sweet, soft, harsh, grating, voluminous, silvery, wooden—names requisite alike in practical life, in science and in poetry. In the diagnosis of the chest, there are characteristic sounds, which receive appropriate names.

Touch proper is cognizant of roughness and smoothness; in combination with muscular feeling, it gives hardness, softness, and elasticity (within limits). The hardness of minerals transcends touch; the harder body scratches the softer; and a scale of hardness is formed upon this test. The pulse is estimated by touch proper, and besides the number of beats, names are applied to signify its tactile modes—as feeble, firm, wiry, steady.

Tastes and *Odours* are provided with names. After indicating the more general modes—sweet, bitter, pungent, we descend to the marked individualities, which are named chiefly (according to the most usual device for supplying terminology) from the substances where they are most marked—acid, alkaline, sooty, game, spirituous, oily tastes, garlic, spice, earthy.

The *Organic Sensations*—Acute pains, Respiratory feelings, Heat and Cold, Digestive feelings, &c., have a nomenclature, partly useful in every day life, and still more extensively involved in the medical art.

Although the Sensations have all an object reference, they yet each contain subjective elements, becoming more and more prominent as we recede from sight and touch; and being almost the whole in the organic sensibilities. Hence their designations are part of the subjective vocabulary, or the vocabulary of *Mind* proper. This is completed by a series of designations for the Special Emotions; for the Will in its various aspects—including desires, appetites, deliberation, resolution, belief; and for the Intellectual processes—idea, memory, reason, imagination, association, agreement.

8. II. There is demanded next a name for every general notion, or distinct product of generalization.

The previous demand is limited to the means of describing every fact belonging to either the object or the subject world. The present relates more particularly to general notions or generalities. But though the two ends are different, the means are in great part the same. All the names of the Terminology are general names; they mean qualities in general, although by their combination they can specify and individualize. Resistance, Form, Colour, Sound, Taste, are general; and their more specific modes heavy, round, blue, melodious, sweet, aro also general. So that the Terminology already contains a provision for expressing numerous results of the generalizing operation.

Still, the aim now propounded is so far distinct from the other, and may require to be separately considered and provided. The results of generalization are of two kinds—classes in the concrete, the subject-matter of the concrete sciences, and qualities in the abstract, which are the characteristic subject-matter of the fundamental sciences—Mathematics, Physics, &c. The names for the first department are not provided for under Terminology; thus, quartz, gold, oak, rose, fish, mammal, are radically distinct from hard, yellow, fragrant, warm—the one group comprises class names, the other the qualifying and descriptive adjectives.

The Terminology coincides much more nearly with the names used in the general sciences; the notions of Mathematics, and of Chemistry (apart from the names of the concrete substances, gold, &c.), are all more or less a part of the *descriptive* vocabulary.

9. It is important that the names of generalities should be short.

The discovery of the relations of general reasoning is facilitated by the brevity of the designations. If we had to employ a long periphrasis for distance, square, gravity, body, it would be impossible to shape an intelligible notion of the law of gravitation, still less to combine it with equally lumbering expressions for tangential force, and for the resistance of the air, in considering projectiles. The advantages of methods of abbreviation are illustrated by the mathematical device of temporarily substituting, for a long formula that has to be treated as a whole, a single letter, *a*; which relieves the mind of what would be a cumbrous impediment.

De Morgan, with reference to the Differential Calculus, to avoid the tedious repetition of 'a quantity which diminishes without limit when Δx diminishes without limit,' coined the word *comminuent*.

An important enquiry is started by Mr. Mill (Book IV., Chap. VI.)., namely, on what occasions we may safely use language as mere symbols, like the symbols of Algebra. Now, the answer to this question is obtained from the nature of such symbols; they are signs of operation, adjusted by careful verification, so that no error can creep in if the rules are adhered to; while the operations are all the more easily and rapidly performed that the things themselves are entirely kept out of view. On the other hand, in dealing with general names, class names, and terminology, we have to keep up a constant reference to the concrete things, as the only way of preventing us from incorrect assertions. After a proposition has once been carefully verified, as 'Knowledge is founded on Agreement and Difference,' we seem to be under no farther necessity of referring to the concrete particulars; which is true only until we begin to apply it. The Formal Logic shows us exactly how far, in matters of general reasoning, we may use language as mere symbols, being to a certain extent analogous to Mathematics, although arriving far short of that science in the possibility of working aloof from all concrete meanings (See Appendix B.)

10. In devising new general names, recourse may be had either to our language, or to foreign languages. Each alternative has its advantages and disadvantages.

The advantage of deriving from our own language is being easily understood; the disadvantage is the presence of mis-

leading associations. 'Damp' would not be a good word to apply to the gaseous form of water; 'vapour' is preferable as being devoid of inappropriate connexions. When Reichenbach conceived that he had discovered an entirely new force in nature, he coined a word not belonging to any language 'odyl.' The generalization of Graham, comprehending substances of a gluey, or viscid nature, with flint, and minerals of the glassy type (showing the conchoidel fracture) is expressed by the term 'colloid' (κολλη glue); the English term being too exclusively confined to the viscid character. 'Inertia' is a useful word, although it demands to be guarded against the too exclusive suggestion of passive resistance.

11. The mere improvements of classification may require new terms.

This is the case with Graham's Colloids and Crystalloids, which arranged previously known substances into a new dichotomy, or contrast, founded on an extensive and important community of attributes. The improved classifications of minerals, plants, and animals, required new terms, monocotyledon, perianth, inflorescence, mammalia, infusoria, &c. Owing to the imperfection of the contrast 'mind and matter,' psychologists have introduced the terms 'subject' and 'object' as exhibiting the antithesis in greater purity.

12. By adapting old names, we may be often saved from a new coinage.

The creation of new terms is sometimes wanton and needless. When there is no new meaning, no fresh product of generalization, the adding of new terms is not justified upon slight pretexts. Apart from increasing the already large burden of language, there is the more serious evil of leading people to suppose that there is a new meaning. Some of Kant's innovations in language are obnoxious to this criticism. His 'analytic' and 'synthetic' judgments 'a priori' and 'a posteriori' have some advantages as synonyms, but the meanings had been already expressed.

A little management may often get over the insufficiency of the existing names. The evil to be complained of is, that a popular name does not exactly square with a scientific meaning; thus the words, force, resistance, motion, affinity, association, are adopted into science; while the popular significations, so far from suggesting, are at various points in conflict with the scientific meanings. Even in such circumstances, the

adherence to the popular words may be a less evil than new coinages. The precautions accompanying the use of old names are these :—

(1) The words may, at the outset, be defined according to their sense in the particular science. Thus, the mathematician defines a point, a line, a square, a cone, a spiral; the physicist defines inertia, force, velocity, attraction, liquid, lever, air, heat, &c.

The chemist defines element, compound, affinity, solution, decomposition. The botanist gives the name 'fruit' to all seed-vessels. The biologist defines life, respiration, digestion. The psychologist defines sensation, idea, memory, association, reason, emotion, sentiment, passion, conscience; all which terms are liable to the loose and uncertain meanings of common speech. The political philosopher defines government, nation, law, order, progress. These various terms being consistently used, in accordance with the several definitions, they are known to possess the significations indicated, and no others, within the sphere of their respective sciences.

This plan was followed in framing the language of Geometry. Names were usurped from common speech, and used in peculiar senses defined at the beginning of Geometrical treatises. Thus a 'sphere' (σφαῖρα), was originally a playing ball, a 'trapezium' (τραπέζιον), a table; but, the scientific sense being defined at the outset, and rigidly adhered to throughout the demonstrations, there was no danger of confusion between the popular meaning of the words and the mathematical.

(2) We may employ, in science, the precaution required in composition, with reference to names having plural meanings, which are abundant in all languages; namely, so to place and fence each word as to keep back all the meanings not intended. The word 'moral' has various distinct significations; yet the use of it in any one place may be such as to admit only one. When we speak of 'moral suasion,' we exclude the meaning of right and wrong, and indicate only 'mental' as opposed to physical. 'The morality of the act was questionable,' shows that moral rightness is intended.

(3) The device of stating the contrary of a term has been seen to be highly effectual in saving ambiguity. 'Reason and not passion prevailed' indicates that 'reason is intended in the peculiar sense of 'motives resulting from rational calculation of the future.'

13. III. In addition to a Terminology, and names for

all important Generalities, there are names adapted for the purposes of Classification.

This is Mr. Mill's third class under the Second Requisite of a Philosophical Language. It refers more especially to the device of double naming (the invention of Linnæus) employed with the lowest kinds, or Species in Botany and in Zoology—'Ranunculus arvensis,' 'Hirudo medicinalis.' In all the higher grades—the Classes, Orders, and Genera—single names are used; but since the number of the objects increases as we descend, while in Botany and in Zoology, the lowest kinds or species amount to many thousands, an abbreviating device is employed, namely, to retain the name of the genus, and designate the species by a qualifying adjective—'Orchis maculata.' The saving of language is not the only advantage of the double-name; there is the additional effect of imparting the knowledge of the genus that the species belongs to, and also the mark or character dividing it from the other species of the same genus Thus, a name so made up gives the place of the species in the classification, so far as effected by stating the genus. The operation could have been carried farther, so as to include the Family or the Natural Order; thus the common daisy would be 'Compositæ bellis perennis.' But this would be held too burdensome.

Under the same head is included the double naming in Chemistry—sulphate of potash, or potassic sulphate. These designations, however, although serving to impart information respecting the substances named, are formed upon a principle quite different from that above explained with reference to the Natural History sciences. They belong to the special peculiarity of the science of Chemistry—the distinction of substances into Simple and Compound, and of Compounds into different modes and degrees of union; and in the case of compounds, they indicate the supposed elements and manner of composition; 'protoxide of iron,' states that the substance named is compounded of oxygen (in a certain measure) and iron. There is scarcely more than an analogy between this class of highly significant names and the double names of Botanical species.

Double naming has not been admitted into Mineralogy. Professor Nicol remarks that the science is not yet ripe for the change. In point of fact, however, Mineralogy is in its nature more nearly allied to Chemistry than to Botany or Zoology; and the double naming if used would not be for species, but for varieties; thus 'magnetic iron' would not be

a proper specific designation; the substance named has a chemical expression, which will always be preferred.

Expressive names may be employed, apart from any system or rule, in all subjects. Thus, in the Natural Orders of Botany, we have such names as 'Compositæ,' 'Umbelliferæ,' which incidentally inform us of some of the characters of the families named. So, the names of the orders of Birds are all expressive of some leading feature.

Whewell proposed to reserve the title 'Nomenclature' for the designations that we have now been considering. Linear, lanceolate, oval, or oblong, serrated, dentate, or crenate leaves, are expressions forming part of the terminology of botany, while the names 'viola odorata,' and 'ulex Europæus' belong to its nomenclature.

CHAPTER III.

CLASSIFICATION.

1. The Methods of Classification grow out of its ends.

I. The *sequence* of the Descriptive characters should follow the order of the properties as expounded in the department.

Considering that a natural kind or species—mineral, plant, or animal—may have ten, twenty, or fifty characters, great importance attaches to the method of stating them. When we seek for a principle to govern this arrangement, we find it in the order of the properties in the general exposition of the science or sciences where they are discussed. Mathematical properties would naturally precede physical, physical would precede chemical, and so on. In an organized being, the tissues precede the organs; and some organs precede others upon the reasons assigned as governing the scientific arrangement or classification of knowledge.

Every classifying science has two divisions—one General, the other Special. The first or General division explains the characters to be used in describing the species, and expounds them more or less minutely. The second or Special division comprises the detail of the objects, and assigns to each its

share or participation in these characters; that is, *describes* the objects.

Thus, in a work on Mineralogy, the General Division comprises *Crystallography*, or the Forms of Minerals; the *Physical Properties*, as Cleavage, Fracture, Hardness, Tenacity, Specific Gravity, Optical Properties, Heat, Electricity, Magnetism; *Chemical Properties*, as Chemical composition and re-actions. This division is an abstract of Molecular Physics and Chemistry. The Special Division, named Description of Species, is the detailed account of all known minerals, according to these properties. For example, Quartz is described as possessing a certain Crystalline form, a peculiar Cleavage, Fracture, &c.

So in Botany. The First Division comprises Structural and Morphological Botany, or the parts of the plant generally —Tissues and Organs—stated on the methodical plan of proceeding from the general to the special, the less dependent to the more dependent. The Nutritive Organs have precedence of the Reproductive; their sub-divisions are taken in the order —Root, Stem, Leaves. The Division is completed by the functions or Physiology of the different tissues and organs.

The Second Division is the Classification and Description of Plants. The complete account of each species then properly accords with the order of the exposition of the constituent tissues, organs, and functions, in the First Division.

In Zoology, the method is still the same, although not so thoroughly carried out as in Botany, on account of the greater complications.

Care should be taken to distinguish ultimate from derivative characters. The Description is fully exhausted by a complete enumeration of what are supposed to be *ultimate* characters. The derivations or deductions from these, if given, should be given as such. A character is to be provisionally received as ultimate, if it cannot be reduced under any more general character.

For example, the support of combustion is a derivative character of oxygen, and does not rank with the properties at present held to be ultimate, namely, the specific gravity, the specific heat, electro-negative position, the combining power generally.

2. II. Observing the golden rule, we must place together, in *classes*, the things that possess in common the greatest number of important attributes.

At the outset of the present department of Logic—DEFINI-

TION, it was necessary to state with regard to the formation of classes of things, that preference is to be given to such groups as contain in common the greatest number of important attributes. This applies to all the modes of dealing with the Concept or Notion. The mind sees objects to most advantage when it views together those that have the greatest number of affinities.

It is on this principle that the vertebrate animals have been classed according to the leading points of their Anatomy and Physiology, such as the manner of bringing forth their young, rather than according to the element that they live in (earth, water, air). The bat flies in the air, but has more real affinities with quadrupeds than with birds; the whale, seal, and porpoise, have warm blood and suckle their young like land quadrupeds, although living in the sea as fishes.

The importance of the attributes is to a certain extent governed by the end in view. For practical purposes, whales are classed with fishes (as in speaking of the *whale fishery*), because their living in the sea determines the manner of their being caught. So, food plants, esculent roots, fruit trees, are groups practically important, but do not coincide with the classifications of botany.

With a view to theoretical science, whose purpose is to assemble in the smallest bulk, and in the most intelligible and suggestive arrangement, the greatest amount of knowledge, the golden rule must be strictly carried out. Even for practical ends taken collectively, this is the most useful plan, from the very reason that it does not defer to any one end in particular. The classifications for practice do not supersede the classifications for knowledge, but are additions to these; they occur in the practical or applied departments of information, as Medicine, Commerce, Law, &c.

Not only in forming groups, but in their juxtaposition in the consecutive arrangement, regard is paid to the amount of affinity. The Natural Orders of Plants and of Animals are so placed, that any two lying side by side are more nearly allied than any other two that could be fixed upon; and alterations are constantly suggested to give proximity to the closest alliances. Thus, Mr. Huxley argues in favour of an arrangement uniting the *Proboscidia* with the *Rodentia*, rather than with the *Artiodactyla* and *Perissodactyla*; the singular ties that ally the Elephants with the Rodents having been a matter of common remark since the days of Cuvier.

3. In aiming at a Natural Classification, that is, one

based on the maximum of important agreements, we may meet with alliances on different sides, of nearly equal value.

Different groups may touch each other at different points, and may have equally strong alliances. Thus, in Botany, the natural order *Solanaceæ*, if viewed with reference to the *pistils*, (the female side), allies itself with *Scrophulariaceæ*; if viewed with reference to the *stamens* and *corolla* (the male side), it allies directly with *Orobanchaceæ*.

Various considerations may be brought forward to determine the choice under such circumstances. One mode is to cast groups into a circular classification, wherein the succession may return to itself. Another mode is an arrangement in two directions, as in a square; an idea carried still farther, although in practice scarcely workable, by a cubical arrangement.

It may, moreover, be considered which method would bring about the maximum of alliance on the whole, or with reference to the entire classification from first to last. In the search after this maximum, we may have to be content with occasional juxta-positions of inferior degrees of resemblance.

Yet farther, we may make provision for *double* placings of the same group, with a view to comparing it on all sides with its congeners.

4. In Zoology, the most natural classification, on the whole, corresponds very nearly with a *serial order* according to the degree of development of Animal Life, and thus facilitates the discovery of laws by the Method of Concomitant Variations.

The great divisions of Invertebrate and Vertebrate, and the sub-divisions of each, represent a gradual rise in the scale of being. The Radiata, as a whole, are lower than the Articulata; the Fishes are the lowest, and the Mammalia the highest class of the vertebrate type. There are deviations from this gradual rise in organization. The *fish* named *amphioxus lanceolatus* is surpassed in complexity of structure by many *insects* and *molluscs*.

For plants, the method is much more qualified. There is a wide interval between the lowest Fungi or Sea-weeds, and the Dicotyledonous Natural Orders, but there is no line of steady progression. The Monocotyledons are not throughout of an inferior grade to the Dicotyledons, nor is there a gradation

among the Natural Orders of either division. The application of the method of concomitant variations is still possible, although greatly limited. It can be seen that the absence of the inflorescence in the inferior plants is conjoined with the cellular structure, which is the lowest organization of the tissue of the plant.

The serial order would apply to all kinds of objects where there is a progress or development, and where the property developed has a commanding importance. Thus, Social institutions, as Governments, may be classed according as they approach to the most perfect type.

The Races of Men, viewed with reference to mental endowment, lie in an ascending scale, with such occasional exceptions as the possessing of some one faculty in a higher grade by a race inferior on the whole. We can thus study the concomitant circumstances of superiority and inferiority in mental development.

Civilization in its larger leaps is linear, but in the minuter differences, not so. Communities advance in special directions, the progress in one line being often accompanied by backwardness in others, from the limitation of the human energies as a whole. It is true of modern as of ancient civilized peoples, that each has its own peculiar excellencies and defects.

> Excudent alii spirantia mollius æra
> Credo equidem, vivos ducent de marmore vultus;
> Orabunt causas melius, coelique meatus
> Describent radio, et surgentia sidera dicent:
> Tu regere imperio populos, Romane, memento;
> Hae tibi erunt artes; pacisque imponere morem,
> Parcere subjectis, et debellare superbos.

5. III. It is an end of classification to save repetition in the description of objects; for which end the generalization is made by successive steps, halting-places, or *grades.*

Instead of describing the species 'elephant' by all its characters, beginning with extension and materiality, the naturalist mentions as specific marks only a small number, and refers to the rest by a series of names expressing what is common to it with other groups.

Whenever two or more individuals agree, the agreement may be stated once for all, and only the difference given under each. In characterizing the races of men, we state first what is common to the whole, and next what is special to each

taken apart. We might apply the method to any two classes that contain agreements peculiar to themselves. There is no natural limit to the process but the existence of agreements. The number of grades may be carried to any length, so long as there is a basis of community. The more complicated the objects, that is, the more extensive the compass of their attributes, the farther may the gradation be carried. The insignificance of the points in common might be a reason for not treating them as resting-points of the gradation.

In Botany there are four principal stages, marking Classes, Families, or Natural Orders, Genera, and Species. These are maintained throughout; while, as occasion arises, intermediate grades are constituted. (See Part First, p. 65).

In Zoology there is first the grand division of INVERTEBRATA and VERTEBRATA. The Invertebrata were divided by Cuvier into Radiata, Articulata, Mollusca, whose farther subdivisions are termed *Classes* (*Infusoria*, &c). The Classes contain *Families* or *Natural Orders*, under which are *Genera*, and under these *Species*. There are thus six regular halting places between the individuals and the summum genus—Animal. The vertebrate Animals descend at one leap to *Classes* (Fishes, Reptiles, Birds, Mammalia). The class Fishes undergoes a division into *Cartilaginous* and *Osseous;* under which are the Natural Orders. The Reptiles, Birds, and Mammalia are occasionally broken up at once into Natural Orders.

The carrying out of the classificatory arrangement demands that by the methods of Definition, the agreements at each stage should be thoroughly ascertained, and fully and precisely stated. The classification by grades is a useless formality if the corresponding characters are not given. The chemical division of simple bodies into Metals and Non-metals is (or should be) accompanied with the characteristic marks or common properties of each class. The farther sub-division of the metals into Noble Metals, &c., is seldom followed up by a rigorous enumeration of all the points of community; and the only advantage gained is the mere proximity of the resembling bodies. The same incomplete adoption of the formality of grades is found in the classification of Diseases; epilepsy, chorea, tremor, hysteria — are classed together, but without the enumeration of common characters.

6 The statement, by successive gradations, of the points of community, is suited to the discovery of Laws of Concomitance.

In ascertaining whether a property a is uniformly conjoined with a property f, there is an advantage in being able to separate the cases where a is absent from those where it is present. This is done in the system of grades. Thus, by isolating the order Ruminantia, we readily discover the concurrence of rumination with cloven hoofs.

If there were any laws of concomitance among the properties of the metallic or the non-metallic bodies of Chemistry, they would best appear in the study of the groups formed upon special properties. Thus, when the metallic substances are viewed together, they readily disclose any conjunctions with metallic peculiarities. So in the non-metallic division, the halogens—Chlorine, Iodine, Bromine, Fluorine, present a narrowed field of conjoined properties.

7. The classifications of Natural objects are understood to terminate with the SPECIES, or lowest Kind; and thus a high importance attaches to the defining marks and boundaries of Species.

In Botany and in Zoology, the view had long prevailed that a species was marked off by community of descent, while any differences that might arise between the descendants of a common ancestor were regarded as varieties and not as specific differences.

The doctrine of the absolute fixity of species is now called in question, and proofs are offered to show that, in the course of descent, differences called specific may arise among the descendants of a common stock. This leads to a modified statement of the doctrine of species. The fact still remains that some characters have a high degree of constancy or persistence through successive generations; while others are liable to change.

Wherever a line can be drawn between highly persistent and highly fluctuating characters, we may call the first specific characters and the others mere varieties. Thus, in numerous species, both of plants and animals, colour is liable to considerable variation within limits. So the absolute size of living objects may alter greatly. Also the *degree* of any quality or endowment, as the strength, or sagacity of an animal, may change. But the tissues, organs, and structural arrangements persist through many successive generations.

Importance may, nevertheless, be still attached to the fact of the fertility or infertility of the unions of individuals. The

horse and the ass are fertile for one generation, but the progeny is incapable of farther procreation.

In Minerals, the boundaries of species are fixed so far as regards crystallization and chemical composition, and all the consequences of these properties. As regards compounds, not chemical, which may take place in all proportions, there can be no fixed lines, although a few grades may be assigned with doubtful margins.

In Diseases, the presence of certain fixed characters, such as the leading symptoms of Inflammation, of Small-pox, of Gout, offers distinctions that may be called specific.

8. In fixing the boundaries of Species, respect may be had to the *number* as well as to the persistence of the characters.

The *Infima Species* or lowest kind, in any of the Natural Kingdoms, is in certain instances divided from all other species by a large number of properties, known and unknown. The characters of the species 'horse' are very numerous; of man still more so. There cannot be the same extent of specific distinctions in the inferior animals; nor in more than a small number of plants. Still, the existence of as many as three, four, or six distinguishing marks, all of some importance and constancy, would suffice for making a species: while the limitation to one or two might leave a doubtful choice between Species and Variety.

Mr. Mill puts the question, are all the classes, in a Natural Classification, Kinds? He answers, certainly not. 'Very few of the genera of plants, or even of the families, can be pronounced with certainty to be Kinds.' In point of fact, the difficulty would be to fix on *any* class of the higher grades, whose properties are so numerous as to rank them with differences of Kind (understood in Mr. Mill's perhaps over-strained language respecting the *Infima Species*).

Another question raised by Mr. Mill is the propriety of Whewell's allegation that 'Natural groups are given by *Type*, and not by Definition.' By a Type, Whewell meant a well-selected average member of a class, removed alike from all extremes; a concrete embodiment of the class, to be used for purposes of identification, in preference to any verbal definition. The motive was the existence of *anomalous* members of many groups in Natural History, which neither conform to the verbal definition nor yet differ sufficiently from the other members to be excluded from the group. We may imagine a group formed upon ten characters, but consisting of individuals that vacillate, some upon one character and some upon another, while yet agreeing in by far the greater number.

We may even make the extreme supposition that the vacillation is such that no single character of the ten persists in every individual; hence, in strictness, there would be no common feature, and yet there would be a very large amount of resemblance.

In commenting on Whewell's mode of getting over the difficulty, Mr. Mill re-iterates his view of distinctions of Kind, which, when fully complied with, can leave no such uncertainty as is supposed. Moreover, he remarks that a class must possess *characters*, that these characters cannot be arbitrary, and must admit of being stated, which is tantamount to Definition.

Probably Whewell's difficulty might be met by the allowance of a doubtful margin, which has been seen to be essential in cases of continuity far less complicated than the demarcations of groups in Natural History.

9. The arrangement of descriptive characters by grades gives the greatest amount of knowledge in the least compass. Yet, for practical objects, it may be desirable to bring together, in consecutive detail, all the characters of a given species.

The genus and species, 'Man' in the class mammalia, is described by the Zoologist, like all the other animals, by giving a certain number of characters at each stage—those common to Vertebrate Animals, to Mammalia, to Bimana (of which man is the sole representative), and finally the marks peculiar to the species. But the human anatomist treats Man in the pure isolation, disregarding, except incidentally, his place in the animated series. So, from the importance of the species 'Horse,' there is afforded a similar exhaustive Anatomy.

Complete Monographs of important species are not only useful for practical ends; they are also the constituent materials of Zoology.

10. IV. The *statement* of characters proceeds, in the last resort, upon a close comparison of Agreements and Differences.

From the nature of knowledge, the highest degree of intelligibility depends upon the most complete exhibition of agreement and of difference.

The classification by grades provides for stating Agreement. A grade, whether Class, Order, or Genus, is defined by the points of agreement discovered among its members. The Botanical class 'Dicotyledon,' has a certain structure of Stem and of Seeds. The Animal genus 'Ovis,' has, as common characters, Horns of a peculiar kind; Hoofs compressed;

Mammæ two; Chin beardless; region between the eyes and nostrils convex.

When characters are stated shortly, as by a mere word or phrase, the tabular method is the most effective; as in minerals. In larger descriptions, the headings at least should stand out distinct. Thus, the genus 'Poppy' is discriminated (from the other genera of the Poppy Family) on two points, one referring to the capsule, the other to the flowers. The generic agreements may be presented to the eye thus:—

'*Capsule*, Globular, ovoid or slightly oblong, crowned by a circular disk, &c.'

'*Flowers*. In Size, rather large; in Colour, red, white, (in the British species) purplish, or (in some exotic ones) pale yellow.'*

The greatest difficulty and nicety belongs to the statement of Differences. Only in dichotomies can this be accomplished to perfection. When a genus has two species, we can put them against each other, according to the plan observed in defining by antithesis or contrast (see p. 164). Thus, in the genus 'Corydalis' (of the Fumitory Family), there are two species (Yellow and Climbing). Their differences admit of pointed contrast as follows:—

YELLOW		CLIMBING.
	Stem.	
Short, erect, branched		Long, climbing, slender.
	Flowers.	
Yellow		Whitish.

If on any one part, there are plural contrasts, the presentation might be varied thus:—

Stem { Short, erect, branched — *Yellow*
Long, climbing, slender — *Climbing*.

When there are several species, the presentation cannot always be effectively given in this manner; some may contain agreements among themselves, as well as differences, which would perplex the contrast. We may, however, occasionally mark off any one from all the rest, thus:—

* Modified from the following description in BENTHAM'S British Flora:—

'Capsule globular, ovoid or slightly oblong, crowned by a circular disk, upon which the stigmas radiate from the centre, internally divided nearly to the centre, into as many incomplete cells as there are stigmas, and opening in as many pores, immediately under the disk. Flowers rather large, red, white, or purplish in the British species, or pale yellow in some exotic ones.'

Opium Poppy.		Other Species.
	Plant	
Glabrous		Stiff hairs
	Colour	
Glaucous		Green
	Leaves.	
Toothed or slightly lobed		Once or twice pinnately divided.

We may always select for pointed contrast the two classes that are most like, and therefore most liable to be confounded. This is done incidentally (although not with systematic thoroughness) in all the classificatory subjects — Minerals, Plants, Animals, Diseases. Thus the Silk-cotton order of Plants (*Sterculiaceæ*) *resemble Malvaceæ* in their general characters, particularly their columnar stamens, but *differ* in their two-celled extrorse anthers. 'In their properties, Capparids *resemble* Crucifers' (difference not stated). The genus Ranunculus is *distinguished* from Anemone by the want of the involucre. In the Field Poppy, *capsule* globular; in the Long-headed Poppy, *capsule* oblong.

11. V. It being requisite to a Natural Classification that bodies be arranged under deep and inaccessible affinities, a separate scheme, of an artificial nature, must be provided as an *Index.*

A classification may accord with the primary rule, and may be defective in the means of discovering the place of a given object. The determination of a plant is puzzling to the beginner in Botany. Now, it was a merit of the Linnæan system to make this comparatively easy; and the advantage was sacrificed in the adoption of a Natural system.

The ideally best classification is one where the properties common to the members of the several groups are both important and obvious. Such a combination is at best but partially realized. Thus, in animals, the important affinities are so far internal, being disclosed only on dissection, as those referring to the minute points of the skeleton, the nervous system, the structure of the viscera, &c.; and so far external, as the form, the external divisions, the integument, and (partly) the reproductive organs. It is fortunate for Zoology that these external peculiarities either constitute of themselves, or are marks of, the important affinities. Still, they are not the whole, and even if they were, a scheme must be formed to guide the student in following them out to the determination

of the name and place of the individual. Such aid has not yet been afforded in Zoology. Yet, without it the most consummate natural arrangement must be a sealed book to all but proficients in the detailed knowledge of animal species.

Chemistry (with Mineralogy) is in a still worse case. The governing principle in arranging chemical compounds being their chemical composition, which is indiscoverable by the naked eye, the determination of a specimen is impracticable without an artificial Index. Owing to the great importance of discriminating substances chemically, in the arts, a method is provided, known as Chemical Testing or analysis, whereby the student, with a limited knowledge of the entire field of Chemistry, can yet determine a large number of bodies.

In Botany, the Index Scheme, or Analytic Key, is highly elaborated. It consists of tables based upon a succession of properties, there being under each a bracket containing two (rarely three or more) alternatives. (See Book V., BOTANY).

In a case of equal importance to Chemistry, the Diagnosis of Disease, an Index classification is still a desideratum. The medical student has no aids to the discrimination of disease short of an aquaintance with diseases generally, after a full study of Pathology. The mode of preparing an Index scheme could be readily gathered from the plans pursued in Botany and in Chemistry.

LOGICAL DIVISION.

12. The rules laid down for DIVISION, as a Logical Process, are rules of Classification, of which Division, in the Logical sense, is merely one aspect.

There are many ways of dividing a whole or aggregate into component parts. A concrete or individual object, as York Minster, may be divided into choir, nave, and transepts; into main building and spire; into walls and roof; into the part for public worship and the private apartments. This is concrete partition, or dismemberment. In much the same way, an ox is divided for consumption. Again, a concrete object is mentally divided, or analyzed, into its *abstract* elements; we may separately attend to the form, the size, the brilliancy, the weight, of the diamond. This is Abstraction. When a plurality of forces concur to a certain result, they often require to be studied in separation; thus, in mechanics, we have to compute moving power and friction apart; in astronomy, the disturbing forces are computed separately, and then compounded.

This is Analysis and also Deduction, or Deductive Combination (See INDUCTION, *Deductive Method*), and is one of the most familiar of scientific operations.

Logical Division is different from any of these modes of separating wholes or combinations into parts. The received rules enable us to judge of its precise meaning and compass. They are the following :—

(1) 'Each of the parts must contain less than the thing divided.'

(2) 'All the parts together must be exactly equal to the thing divided.'

(3) 'The parts must be opposed,' that is, 'mutually exclusive.'

Hamilton adds (4) 'The principle of Division should be an actual and essential character of the divided notion ; and the division, therefore, neither complex nor without purpose.'

These rules point to an actual, exhaustive, single-purposed, and important division. The first rule points to an actual division, for unless the parts be less than the whole, the whole is not divided. The second rule supposes that the parts are to be exhausted, so that we may declare everything contained in the whole to be found in one or more of the parts. There may be divisions where this is not insisted on. The third rule requires that the division shall be upon one purpose or plan, so that the parts may be mutually exclusive : we divide an army into infantry, cavalry, and artillery ; or into officers, non-commissioned officers, and rank and file ; but not into infantry and commissioned officers. The fourth rule indicates that divisions should not be on trivial or insignificant characters, as if we were to divide an army or a population into persons with names of one syllable, and persons with names of more than one syllable.

The real importance of these rules is with reference to Classification ; for other purposes they are idle, and even erroneous. When a comprehensive class, as Vertebrata, has to be sub-classed, we must comply with the conditions of classification generally, or such as we observe in the march upward, from the lower to the higher grades. The Vertebrata are divided or sub-classed into Fishes, Reptiles, Birds, and Mammals; it being obvious that each sub-class is less than the whole, that all the four sub-classes amount to the whole ; and that each sub-class excludes all the rest. If there were a failure on any of these points, the classification would be bad ; the field of the sub-divisions is supposed to be exactly the field of the entire group ; nothing is to be left out, and nothing

counted twice. So in every case of genus and species. If we mean to give all the species, we should give them all. Moreover, a division into species, where the same individvals appeared in two species, would confound the very idea of specific distinctions. If the bat were placed among birds, and also among mammals, there would be two conflicting principles of classification.

Division, in the logical sense, is thus merely a way of looking at classification by grades. Hamilton's additional rule—that the principle of Division should be essential and important—is the golden rule alike of defining and of classifying.

A division, or sub-classification, is complete when we may disjunctively affirm a member of the class as in one or other of the parts. 'Actions are either good, bad, or indifferent,' supposes that Actions may be exhaustively and correctly divided or sub-classed into good, bad, and indifferent; it being understood farther that the same action is not both good and bad, good and indifferent, or bad and indifferent.

A classification may be conveniently tested by the rules of division, especially the third, the violation of which makes the Fallacy of Cross-division. Thus, the old classification or division of the Virtues, called the Cardinal Virtues—Justice, Prudence, Courage, Temperance—is vicious; and the viciousness may be expressed as either a bad classification or as an illogical division; for Prudence includes the whole of Temperance, as well as all that part of Courage that conduces to self-interest.

The Analysis of a Compound is necessarily exhaustive; it is the purpose of analysis to ascertain everything that enters into the given combination. A chemist examines a meteoric stone, with a view to determine all the chemical elements present. The physiological chemist desires to find out all the constituents of blood, of bile, of gastric juice, of flesh, and so on. To such cases, the rules of Division might apply, if anything ever turned upon them.

The ultimate analysis of the Mind, whether in whole or in part, might be tested by logical division. Thus, Mind as a whole is divided into Feeling, Volition, and Intellect; and to this division the logical tests should apply. The three departments should exhaust the mind without going beyond it; and they should be mutually exclusive. So in the Intellect, the analysis into Discrimination or Difference, Agreement or Similarity, and Retentiveness, professes to be an ultimate analysis; the three functions ought to contain all that is intellectual and

nothing more; while each should contain nothing in common with the other two. The old enumeration of the Intellectual powers—Memory, Conception, Abstraction, Reason, Judgment, Imagination—is not a logical division; it could not be shown to be intellect, all intellect, and nothing but intellect; while the members are not mutually exclusive; memory has something in common with all the rest.

13. Logical Division fails in classifications with undefined boundaries.

The rules of Logical Division are inapplicable to classifications growing out of combination, growth, or development. Such are the compounds of chemistry, the offspring of living bodies, the developments of human knowledge, the associative growths of the mind. All these products are naturally unlimited and inexhaustible. Oxides, carbonates, silicates, alkalies, ethers, are interminable; their particulars cannot be enumerated; no enumeration necessarily takes in the whole.

In the Human Mind, the Senses, or primary elements of sensibility, comply with the rules of Division. The Emotions, most of which are growths or developments, do not comply with it. If any of the emotional states were strictly ultimate, they would be mutually exclusive; but there are very few such; Wonder, Fear, and Love, are nearly ultimate, but may not be wholly so. The great bulk of the Emotions being growths out of common elements, they cannot have a strict mutual exclusion; yet they may have distinctive characters, and may be properly viewed as emotional species. Love, Self, Power, Irascibility, Pleasures of Knowledge, Beauty, Moral Feeling—are all well-marked groups of emotions, but they are formed out of common elements, which are perceptible to our self-consciousness. As products of growth or association, they have no fixed number; new occasions would give rise to new varieties or species; and there cannot be a mutual exclusion. They are subject to the golden rule of classification, but they do not present a case for logical division.

There is a similar inapplicability to the classification of the Sciences; these also succeed one another by growth or development. Chemistry involves Physics, and Biology, Chemistry. The Natural History sciences—Mineralogy, Botany, Zoology, Geology—are full of unavoidable cross-divisions and double entries. In such a science as Materia Medica, there are many double entries; the same substance is at once stimulant and narcotic. The Social Sciences—Politics, Political Economy, Jurisprudence—cannot be made mutually exclusive.

BOOK V.

LOGIC OF THE SCIENCES.

To exhibit the principles and rules of Logic in a new aspect; to indicate the fields where these are most needed, and where examples are provided with inexhaustible fulness,—we shall review in order the Theoretical Sciences, and some of the leading Practical Sciences.

CHAPTER I.

LOGIC OF MATHEMATICS.

1. In Mathematics, logically viewed, there is afforded the most consummate exemplification of a Formal Deductive Science.

The processes of Deduction are seen to advantage in Mathematics. The Definitions, Axioms, Demonstrations, Symbolical language, and various devices for multiplying the relations of quantity, the subject-matter of the science, exhibit all the machinery for performing Deductive operations of a Formal nature.

2. Mathematics treats of QUANTITY in the Abstract, so far as susceptible of definite expression.

The first, the deepest, the most fundamental experience of the human mind is Relation, or Relativity; this is implicated in the very nature of consciousness. The doubleness, the essential two-sidedness of every conscious experience is a fact that has no forerunner. Of the differences, contrasts, or correlative couples, starting immediately from this primary condition, the first is difference in Quantity or Degree—the distinction of *more* and *less*.

Quantity adheres both to subject and to object, but it is not always definite; and none but definite expressions enter into Mathematics. The most definite form of quantity is NUMBER, or discrete quantity—one, two, three, &c. Continuous or unbroken quantity is made definite chiefly by its being broken artificially and made numerical. In a few instances, as in the geometry of Incommensurables, definite relations can be expressed by lines in figures; such is the relation of the side to the diagonal of a square. A difficulty of a metaphysical nature has long attended the mathematical expression of continuous quantity in these incommensurable relations.

Notions of Mathematics.

3. An enumeration of the principal Notions occurring in Mathematics, prepares us for ascertaining the character of the propositions.

The chief notion is *Equality*, with its opposite Inequality. This is the prevailing predicate in Mathematics. Likeness (implicating unlikeness) applied to amount or degree gives Equality. There may be likeness in other properties, as sound, colour, pleasure; but, except in quantity, there cannot be Equality. We can both discriminate and classify, apart from Mathematics, but when we declare things equal or unequal, we are announcing propositions purely mathematical.

In detecting equality, the final appeal is to sense or consciousness. For Number, we identify a succession of beats, or remitted impressions, as two, or three; this is the surest judgment that the human mind can form. For Continuous Quantity, we discriminate grades of continuance by the sense proper to the peculiar effect—the eye, the ear, the touch, &c.: the most delicate discrimination, and the one that, if possible, all others are reduced to, is *visible extension;* next in rank is the continuance of sound. Euclid's definition of Equality is the *visible* coincidence of extended magnitudes.

Number is thus seen to be a fundamental notion of Mathematics, as the science of Quantity. Interrupted sensations, or transitions, of consciousness, are vividly discriminated; and by memory we can easily retain a small succession of these, and identify it with another small succession. Thus, three coins seen by the eye, are identified to a certainty, with the three fingers, in respect of the number of interruptions or transitions; they are felt to be different from two or from four visible transitions. This is numerical equality or inequality.

For the higher numbers, artificial aids are requisite to ensure certainty of comparison; but with such aids (namely, orderly groupings) we can compare numbers of any amount; we can identify one hundred in two different aggregates of that number, and discriminate one hundred from ninety-nine.

Names are given to the successive numbers, one, two, three, four, five, &c.; at the number ten, a group is formed, and we start afresh. This is our *decimal system*, to which correspond the designations *units*, *tens*, *hundreds*, &c.

Addition is the next fundamental notion; also obtained, in the last resort, from the senses. When we bring two detached groups or successions from different places to the same place, or into one continuous group or succession, we are said to add; the implicated contrary is to *Subtract*. The names *whole* and *part* refer to the same operation, and are explained by the same experience. *Multiplication* is merely a continued addition, and its obverse is *Division*. These notions are the names of the four cardinal processes of the manipulation of numbers. Related to them are the meanings of sum, difference, remainder, factor, product, dividend, divisor, quotient, prime number.

Fraction (*versus* Integer) grows out of division; also the designations *numerator* and *denominator*, *common measure*. To fractions are applied the cardinal operations—addition, &c.

Decimal is a fractional mode, related to our decimal enumeration.

Square, *cube*, *square root*, *cube root*, &c., are special growths or extensions of multiplication and division respectively.

Ratio is the statement or implication of how many times one number is contained in another; the ratio of three to twelve is *four*, or one to four. We do not always reduce the ratio to the lowest terms; we may speak of the ratio of three to six, but the comparison of the numbers is by multiplication or division. The expression of ratios takes the form of *fractions*.

Proportion is equality of ratios; three is to eight in the proportion of nine to twenty-four.

Ratio, Proportion, and Fraction, conduct us to the idea of *Incommensurable*.

Progression, or *series*, is a succession of numbers according to a fixed law; the *Arithmetical* progression being governed by addition, the *Geometrical*, by multiplication. A progression contains *Extremes* and *Means*.

Permutations and *Combinations* are modes of operating upon numbers that need not here be explained.

Logarithm signifies a still more advanced notion; being the name for an entirely novel mode of expressing the relations of numbers, which, when unfolded in tables, greatly reduces the labour of the higher operations, namely, multiplication, division, raising to powers and extraction of roots.

The foregoing comprise the leading notions of mathematics for the initial branch, called pure ARITHMETIC. For Concrete or commercial Arithmetic, there are involved farther the money standards, the weights and measures, together with the adaptation of the cardinal processes of proportion and of fractions, to compute these several varieties of concrete quantity.

ALGEBRA carries forward all the arithmetical notions to a new order of expressions of quantity. The detaching of the operations from the actual numbers, by the use of symbols, gives new designations, *Negative Quantity*, *Index*, *Exponent*, *Surd*, *Impossible Quantities.* The general theorem for expanding by powers or roots is the *Binomial Theorem.* Then follows the *Equation*—Simple, Quadratic, &c.

The Notions of GEOMETRY are comprised in the Definitions of Euclid:—Point, line, straight line, curve line, angle, parallels, surface, solid, triangle, quadrangle, polygon, circle, cube, sphere, cylinder, cone, &c.

In TRIGONOMETRY there are new designations—sine, co-sine, tangent, secant.

In CONIC SECTIONS are comprised the figures so named with the further designations—eccentricity, focus, directrix, latus rectum, parameter, abscissa, normal, asymptote.

ANALYTICAL GEOMETRY involves *co-ordinates* and *loci*; and designates a number of curves reserved for analytical handling—cissoid, conchoid, witch, lemniscata, catenary, cycloid, involutes, spirals, &c.

The higher CALCULUS introduces us to the notions—Infinitesimal, Differential, Integral, Limit, Dependent and Independent, Variable.

Propositions of Mathematics.

4. In the logical aspect, these propositions are leading examples of the predicable, called *proprium.* The predicate is deducible and demonstrable from the subject.

The Axioms are inductions of concomitant properties. In all other propositions (excepting those that are in reality *definitions*), the predicate is deducible from the subject through the axioms. Thus, in the simple Arithmetical proposition, six

times four is twenty four, the predicate (24) follows from the subject (6 times 4) by the medium of the two great axioms of equality. The predicates are not contained in the subjects by necessary or immediate implication; they are mediate inferences drawn by the help of the highest generalities; exemplifying the true nature of the *proprium*.

Definition in Mathematics.

5. Certain of the Notions of Mathematics are fundamental and indefinable; the rest are defined by derivation or Analysis.

It will be sufficient to advert to the specialities connected with (1) Arithmetic, and (2) Geometry.

Definitions of Arithmetic.—We have seen that Number or discrete quantity, is a series of intermitted impressions on the mind—patches of colour, sounds, &c. This is an ultimate fact; language can give no account of it in any other way than by calling each one's attention to their own experience. As regards the numbers themselves, experience must give us a few to begin with; the rest may be derived and defined from these. Unity is an ultimate reference, the abstraction from numerous concrete objects, that is, from many single impressions; it is contrasted with two, and with the higher successions. We learn one, two, three, four, five, &c., by repeated experiences of the successions so named; the hand is a familiar example of five. We might go a good way in distinguishing the successive numbers, but, in point of fact, when a dozen or thereby is reached, we resort to modes of comparison that imply grouped arrangements.

So much for our actual experience of numbers, which is presupposed in the attempt to define them. For the actual purposes of a strict definition, we must assume *one* as indefinable, that is, as already known. Even this supposes that we know *two* at least, for, without a contrast with plurality, we cannot possess the meaning of unity.

Before going farther, it is necessary to suppose that we understand *addition*. This is an abstract notion gained from many concrete experiences of accumulating objects in mass. We cannot define it; we must point to the operation: an operation, as already remarked, that makes known *subtraction* likewise; and also *whole* and *part*. To attempt to define any of these notions is to encroach upon the ultimate experiences of the mind; and the futility is shown by the words employed,

'aggregation,' &c., which are not more elementary, or more simple, than the notions that they are used to define.

With a knowledge of *one*, and of *addition*, we may begin to define. The lowest definable number is then *two*; we may define it by the addition of one and one. The rest follow: *three* is two added to one; *four* is three and one; five is four and one, and so on. Each number is definable as one added to the previous number. Arriving at ten, we bring into play the decimal notation, or the grouping by tens, which gives us double expressions: eleven is ten and one, twelve is eleven and one, and also *ten* and *two;* fifteen is fourteen and one, and also ten and five. We may be supposed at this stage to make use chiefly of the second form, although always aware of its equivalence to the first; sixteen is ten and six; twenty-seven is twenty (two tens) and seven.

All the other notions of Arithmetic are susceptible of definition properly so called; they may be derived from the notions now given. In logical strictness, there is no need for a farther appeal to experience; although the actual understanding of the processes is aided by using concrete examples of numbers and their formations.

Definitions of Geometry.—The difficulties here are far more serious; yet the proceeding is the same. We must recognize a certain basis of the indefinable, a resort to experience for what can be given only by experience.

By experience, we become familiar with all the modes of extension, and learn the names for them. We know solid bulk, surface or area, length, angle, direction, straight, bent, curved, parallel, and so on. We also know what a Point is, in the peculiar acceptation of a landmark, or a place to measure from, to begin, to terminate, or to divide a length. While Solid Bulk is the one concrete fact, all the rest are abstractions, and we learn to understand them in that character. We can consider a line, or length, without affirming anything of the breadth of the thing discussed; we can restrict our affirmations to what would be true under any width, as when we say a piece of string and a plank are of equal lengths. By a large concrete experience of this nature, we are prepared for the more rigorous methods of arranging and stating these notions in Geometry.

To advert more particularly to our experience of Lines or lengths, abstraction being made of the accompanying breadth and thickness. In this one experience is wrapt up inextricably a whole group of the notions given by the geometer in separa-

tion. In working with rods, with strings, with wires, and other things, we learn, not only length (as greater or less), but also the difference between straight and bent, crooked or curved; together with direction, angles, and parallelism. Straightness, direction, angle, convergence, divergence, and parallelism, however separated in Geometry, are all intermingled in our primitive concrete experience; and, indeed, any one would be incompletely understood if it did not involve all the rest. We cannot understand the full force of 'straightness' without understanding what is meant by direction: 'direction' would be very incomplete without involving the meaning of an angle; and the concrete experience of an angle gives all that is meant by convergence and divergence, and also by the opposite of these—parallelism.

All these notions, therefore, have to be assumed as being perfectly intelligible and as wholly indefinable. We can assign nothing more simple or more elementary to define them by. The attempt to define an 'angle' only returns upon itself; thus, an angle is said to be *the inclination of two lines*, but 'inclination' is merely another name for angle; as well say, 'an angle is an angle.'*

Geometry, as well as Arithmetic, is a Deductive Science. Now it is the idea of a deductive science to assume the fewest notions possible, and to begin to define, or derive, as soon as there has been laid an adequate foundation in the indefinable.

To make the application to the case in hand. The fewest elementary notions that we can proceed with may be differently stated by different persons; but one cannot be far wrong in the following:—point or landmark, line or length, straight, as contrasted with bent, angle, surface, solid. The three—line, straightness, angle—are really phases of one experience; and, by a great stretch of ingenuity, we might find it possible to condense the three expressions into two, or even into one; for undoubtedly the line (as carrying with it length) implicates

* 'Geometrical definitions are of three kinds: (1) Those which express our primary ideas of space, such as the definitions of a straight line, an angle, a plane, &c. (2) Those which by means of the first class define certain simple *forms*, the *triangle*, the *square*, and the *circle*, from the properties of which all calculation of relative positions and superficial magnitudes is derived. (3) Definitions of other forms, as the rhombus, trapezium, hexagon, ellipse, &c., the properties of which are found by the application of theorems obtained from the definitions of the simple forms.' (CHALLIS ON CALCULATION, p. 61).

The last named class exemplify what are called **Deductive Definitions** (p. 165).

'straightness,' which itself involves its opposite 'bending,' and also 'direction;' and from direction we cannot separate change or variety of direction, as exhibited in an 'angle.' Notwithstanding this inevitable mutual implication, we may retain the above enumeration of primary or indefinable notions —*point*, *line* or length, *straight* (with *bent*), *angle*, *surface*, *solid* (it would be a vain refinement to treat 'surface' and 'solid' as derived from length, or *vicê versa*). From these we are able, by proper analytic definition, to give an account of all the other geometrical notions. It is requisite, however, to unfold the immediate implications of each, and to state which phase, aspect, or property shall be put forward, in the subsequent demonstrations, as the *testing* property.

Point.—As stated, this is the same meaning as landmark; for geometric purposes, we hold it as the beginning, division, or end, of length or a line; all which must be understood by actual experience.

Line or *length.*—It is impossible to give a definite meaning to 'line' without at once distinguishing the *straight* from the *bent* line; it is only the straight line that is synonymous with 'length.' The mutually implicated notions—length and straightness—are absolutely incommunicable by any device of language; they cannot even be made clearer by discussion. We may, however, select *one feature* or aspect as the *test* to be referred to in the course of the demonstrations, namely, that 'two straight lines, if made to coincide in two points, will coincide wholly,' will have no interval; all which ideas the learner has to bring with him from his own independent experience. Another aspect of the straight line, sometimes given as its definition, is 'the shortest distance between two points;' this, however, may be proved by proper demonstration; being a corollary to the proposition that two sides of a triangle are greater than the third. At the same time, it is sufficiently implicated with our experience of lines to be received without proof.

Angle.—This also must be known from experience. We must see with our eyes two straight objects meeting with a greater or less opening. That experience supplements our education in 'direction,' and gives us what is meant by 'divergence' and 'convergence,' greater or less. There is a farther implication of two lines running side by side, and neither diverging nor converging; to this fact we give the designations 'sameness of direction' and parallelism;' all incommunicable notions.

It may then be *formally* proper to describe an angle as two straight lines meeting in a point, with greater or less divergence. This is merely one way of referring us to our experience of the fact; and it is thought the best workable test of an angle in the subsequent references.

With the angle, we can conveniently connect the notion of 'Direction.' Inasmuch as all direction is relative, there must be two lines given, and the angle they enclose gives the comparison of the two directions. Direction being understood, we can define a curve line, as a perpetually changing direction; which is an obverse equivalent of Euclid's phrase 'a line of which no part is straight;' both expressions being proper to be retained.

Parallels.—These are inevitably understood along with the notions already given. As to their formal, or test definition, Euclid's original expression, 'two lines in the same plane, produced ever so far both ways, and yet not meeting,' is properly a negation of both convergence and divergence, and is sufficiently workable, which is all that need be said for any definition.

Plane Surface.—This is clearly an incommunicable notion. It would be superfluous to construct it by the help of lines, for, while we are learning lines, we are also learning surfaces. All that is needed is a convenient testing peculiarity, such as that given by Euclid,—'any two points being taken in a plane, the straight line joining them lies wholly within the plane.' The notions 'within' and 'without' must be got from our manifold experience of extended bodies.

Solid Bulk.—Also incommunicable by any simpler notions. If we seem to define it by combining the notions of 'planes' 'directions,' &c., we in reality repeat ourselves; for these very notions were attained by a mass of experiences including solid bulk or volume.

The elementary notions now enumerated being once obtained from experience, the remaining notions of geometry are definable by referring to these. No new appeal to the senses is absolutely required in defining a right angle, a circle, a triangle, a square; although we are constantly aided by concrete representations in understanding these notions.

Axioms of Mathematics.

6. The Axioms of Mathematics should conform to the conditions of an axiom, namely, (1) they should be real

propositions, and (2) they should be underivable from any other principles within the science.

An axiom is, in the first place, a real proposition, and not a verbal or essential proposition. The axioms are the groundwork of all the reasonings in the science, but no reasoning can be based on merely verbal propositions.

In the next place, the axiom should be absolutely fundamental and underivable within its own science. All that is characteristic of the axiom is surrendered, if we admit deduced principles. The axioms are the undeducible grounds of all the deductions.

It is not a proper account of an axiom to say that it is a *self-evident proposition*, or a proposition assented to as soon as pronounced. This may or may not be the case. Some axioms are self evident, others not; and many principles that are self-evident are not to be received as axioms.

Axioms of Mathematics as a whole.—The axioms of Mathematics as a whole, requisite to be given at the threshold of Arithmetic, are at least these two—'Things equal to the same thing are equal to one another,' and 'The sums of equals are equals.' These are real propositions, inductions from experience, and undeducible from one another. Whether they are sufficient for all purposes, will appear afterwards. Both are demanded by the processes of Arithmetic.

Axioms of Geometry.—As it has been the practice to teach Arithmetic to beginners, not as a reasoned or deductive science, but as a series of rules given upon authority, and merely confirmed by their actual results, the mathematical axioms usually confront the learner for the first time at the beginning of Geometry, which from early ages has aspired to be, not merely a body of correct rules for measuring magnitude, but a perfect type of deductive reasoning. As thus presented, the axioms of all Mathematics are so mixed up with matters belonging to geometry in particular, as to seem exclusively geometrical in their bearing. These axioms, made familiar to us by Euclid, have to be tried by the two tests already laid down.

In Euclid's original text, there occur *twelve* axioms (or common notions *κοιναὶ ἔγγοιαι*). Others have been added by modern editors; it is not unusual to give *fifteen*. The two first in the enumeration are the two already mentioned as unquestionable axioms, conforming to both the criteria. The five succeeding are—

(3) If equals be taken from equals, the remainders are equal.
(4) If equals be added to unequals, the wholes are unequal.
(5) If from unequals, equals be taken, the remainders are unequal.
(6) Doubles of the same are equal.
(7) Halves of the same are equal.

Now, these are all real propositions, and therefore not disqualified by the first condition; but as they are all very easily deducible from the two first, they fail to comply with the second condition. They are not axioms proper, but deductions or corollaries from axioms, and should be demonstrated. If we are to call them axioms, there is nothing to prevent us from calling any real proposition whatever an axiom. It violates the very essence, the first demand, of a deductive science to take for granted without proof whatever can be proved from another principle within the science.

The eighth axiom, 'Things that coincide, or have the same boundary, are equal,' violates the first test of an axiom; it is not a real proposition, but a definition of equality. 'Coinciding' and 'being equal' are not two facts but the same fact in two statements of language, the one being given as the explanation of the other. Equality as applied to extended magnitude is coincidence to the senses; to prove equality we prove coincidence. Of Equality no definition can be given in the last resort; it is the feeling of similarity or identity as applied to quantity. But in dealing with the special kind of quantity considered in geometry, there is a convenience in specifying the test of equality belonging to the case—namely, the visible coincidence of the boundaries of the two things compared—lines or plane figures. The supposed axiom is therefore the geometrical statement and adaptation of the fundamental and indefinable notion of equality.

The ninth axiom is 'The whole is greater than its part.' This also violates the first test; it is not a real proposition; the predicate is not different from the subject. It is a property implicated in the common fundamental notion that gives a meaning to *addition, subtraction, whole, part.* The concrete experience implied by all these words is one and the same experience, and in it is implicated the fact that what we call a *sum* is greater than any one of the amounts summed up; or what we call a *whole* is greater than any of the *parts.* We could not possess the notion of whole and part without

possessing the fact that the whole is a larger magnitude than the part. If, therefore, there be any necessity for distinctly announcing this peculiar aspect of the great fundamental notion of *addition*, it should be given as one of the forms of expressing the notion of Addition, when that notion is first introduced at the threshold of Arithmetic.

The tenth axiom, 'All right angles are equal' is implicated in the definition of a right angle; and should be stated as an appendage to that definition.

The eleventh axiom, in Euclid's text, is a difficult theorem preparatory to the propositions respecting parallel lines. It is usually given in a modified and simpler form. Thus (by De Morgan)—'If a straight line be taken, and a point exterior to it; of all the straight lines that can be drawn through the point, one *only* will be parallel to the first-mentioned straight line.' In whatever form given, it is not an axiom, but a proposition deducible from the definition of parallel lines; in fact, it ought to appear among the Theorems of the first book, unless, indeed, it be so nearly identified with the definition of parallels that it can be given as a mere various wording or obvious implication of that definition; which, however, is hardly the case.

Euclid's twelfth (and last) axiom is famous in the History of Philosophy: 'Two straight lines cannot enclose a space.' It is not a real proposition, but merely an iteration of the very fact of *straightness*. The *pro forma* definition of this indefinable notion is 'When two lines cannot coincide in two points without coinciding altogether, they are called straight lines.' Now it is a synonymous variety of the expression 'coinciding altogether,' that there should be no intervening space. That the lines should be 'straight' and that they should 'enclose a space' would be a contradiction in terms. This axiom must, accordingly, be rejected; the phrase 'not enclosing a space' being transferred to the definition of straightness, as an emphatic obverse iteration of 'coinciding altogether.' We might express it thus—'When two lines cannot coincide in two points without coinciding altogether, that is, without excluding an intervening space, they are called straight lines.'

In the modern texts of Euclid, there are added to the list of axioms such propositions as the following.—'If two things be equal, and a third be greater than one of them, it is also greater than the other.' This is clearly demonstrable from the proper axioms, coupled with the notions of greater and less.

More notable is the *argumentum a fortiori*, occasionally imported into Logic, although in its nature strictly mathematical. If A be greater than B, and B greater than C, much more is A greater than C. Every one readily assents to this principle as an induction from facts of their own observing. If it cannot be deductively inferred from the two proper axioms, it will have to be received as a third axiom. Probably, however, mathematicians would be able to demonstrate it, if not directly, at least by *reductio ad absurdum*, from those axioms.

Another example of a proposed axiom is the following:—'Of all lines that conjoin two points, there must be one with none less; if only one, that is the least.' If there is any necessity for enunciating this circumstance, it should be given as implicated in our experience of lines; its opposite is a contradiction in terms; the very meaning of 'least' is that there can be nothing less.

The bringing forward of axioms at every new stage of Geometry is wholly at variance with the deductive character of the science. There may be required a class of principles, intermediate between the axioms proper and the demonstrated theorems; but they should not be confounded with the primary foundations of the science; they should have a name distinct from 'axiom.' If inconvenience were now to arise from dropping the name in connexion with these preliminary principles, some emphatic designation should be adopted for the really fundamental truths—'Axioms-in-chief,' 'Axioms proper,' 'Indemonstrable assumptions,' 'Final Inductions.'

The Postulates.—These are the groundwork of the constructive part of Geometry—the problems, as distinguished from the theorems. It is Euclid's plan to carry on, side by side, a series of problems of construction and a series of theorems; the constructions being required for demonstrating the theorems. These constructions, however, have an independent value for practical applications; the land measurer follows Euclid's method in throwing out a perpendicular from the side of a field. Now, in constructing, as in demonstrating, something must be assumed at the outset; and these assumptions are to be the fewest possible. Accordingly, Euclid starts with demanding three operations—drawing a straight line from one point to another, prolonging a given straight line, and describing a circle; in concrete, he requires the student to have a ruler and a pair of compasses.*

* 'The Postulates which are prefixed to Book I. require us to admit that certain geometrical operations may be performed, without respect to the

It is averred that, in the course of Euclid's demonstrations, tacit assumptions are occasionally made, such as should have been placed among his axioms. Thus, in the fourth proposition, there is an assumption that a figure may be lifted and turned upon itself without change of form. This, however, is part and parcel of that great step, the very earliest to be made in geometrical proof, whereby the comparison of two plane figures is achieved. As regards the first proposition, Mr. De Morgan points out two postulates that should have been explicitly given with the others; and, for the twelfth, two more postulates are necessary (Companion to the British Almanack, for 1849).

The leading branches of Mathematics :—Arithmetic.

8. The foundations of Arithmetic are the two proper Axioms of all Mathematics, the Definitions of the fundamental operations—Addition, &c., and the Definitions of the Numbers. The *Propositions* flow deductively from these Axioms and Definitions combined.

The Axioms being premised, the Operations understood and the Numbers defined, the deduction or demonstration of the Propositions easily follows.

The Propositions of Arithmetic affirm or deny *the equivalence in amount of numbers differently aggregated.* The following are examples. Six and seven is equal to nine and four, to ten and three, &c.; that is, a row of six and a row of seven would be the same total aggregate as a row of nine and a row of four. These are propositions of addition. As there is one standard mode of expressing aggregates—the decimal system, the arithmetical propositions usually take the form of stating other modes of aggregation as equivalent, or not, to a given decimal aggregation; nine and five is fourteen (the decimal aggregate—ten and four). There are corresponding propositions of subtraction; nine taken from fourteen leaves five.

manner of performing them. In fact, they appeal to our *conceptions*, and for all the purposes of reasoning might be expressed thus:

Any two points may be conceived to be joined by a straight line.

Any terminated straight line may be conceived to admit of unlimited extension.

A circle may be supposed to have any position for its centre, and a radius of any magnitude.

The following is another postulate of the same kind, which we shall have occasion to refer to hereafter :—

A straight line passing through any point may be conceived to be parallel to another straight line' (CHALLIS ON CALCULATION, pp. 63-4.)

The proof of such propositions is the application of the axioms to the definitions of the numbers as already given: the axioms are the major premises, the definitions the minors. Thus, to prove that three and four is seven, in other words, that a row of three together with a row of four is the same as a row of seven. We may proceed as follows:—

By the definition, 3 is $2 + 1$ (or again $1 + 1 + 1$).

Hence, $4 + 3$ is the same as $4 + 1 + 1 + 1$.

Now $4 + 1, = 5$; $5 + 1 = 6$; and $6 + 1 = 7$.

The warrant for these substitutions is the law 'the sums of equals are equal,' applied thus:—

$$1 + 1 + 1 = 3.$$

Hence $4 + 1 + 1 + 1\ (7) = 4 + 3$.

Arithmetical probation thus, at the outset, creeps along by a unit at a time; when, in that way, larger leaps are established, the deductions are much shorter. For example, we can construct and commit to memory a table for the addition of every two numbers up to ten (2 and 3, 2 and 4, &c).

Propositions of multiplication—six times eight is forty-eight—are a mere extension of the process of addition. The celebrated multiplication table embodies 144 of these propositions, and, by implication an equal number of propositions of division.

Thus, while the affirmation '3 and 1 is 4,' is a verbal proposition (being declaratory of the meaning of 4), '2 and 2 is four' is a real proposition deduced from the induction 'the sums of equals are equal.' This last is sometimes called a necessary truth, but it is not necessary in the sense of an identical or implicated truth; it is true only if the above axiom be true. It is sometimes called self-evident, but that merely means that it is very rapidly appreciated; it is essentially of the same scientific character as 16 times 16 is 256, which would not be called self-evident.

As there is no limit to Numbers, so there is no limit to the propositions asserting (or denying) the equivalence of numbers differently stated.

Algebra.

9. The vast mechanism of Algebra rests upon the fundamental axioms of all Mathematics. It is a great extension of the compass of Arithmetic depending upon using *symbols of numbers,* and *signs of operation,* for actual numbers and actual operations.

No new principles of reasoning or computation are introduced into Algebra; its foundations are sôlely the axioms common to all mathematics. Its characteristic feature is, in the place of actual numbers, to employ symbols representing numbers generally; and, for the actual operations of addition, subtraction, multiplication, division, to use *signs* of operation, $+$, $-$, $\times$, $\div$, &c.

Numbers are no longer compared by their actual amount, but by their modes of formation. One number is regarded as made up of others formed in a particular way, shown by the signs of operation. A number a is given as made up of the sum of b and c, as $b + c$; or of the product of b and c, as $b\,c$; or of the square of b, b^2. On this scheme the one number is said to be a *function* of the others; and the science of Algebra is said to be the calculus of Functions.

The simple functions of numbers are few, being the expression of the elementary relationships—addition, subtraction, multiplication, division, powers, roots, logarithms, sines.

Mr. Challis distinguishes between Algebra and the Calculus of Functions. He restricts Algebra to the instrumentality and manipulating of *Equations*. Algebra is a more highly generalized scheme of symbolical expression than Arithmetic; it represents quantities by letters, a, b, x, y, which may have any numerical value, the only thing considered being their relationships to one another, as sums, differences, products, roots, &c The Calculus of Functions is a still farther step in the same direction. It uses symbols to show that one quantity has relationships to others, without condescending on any one form of the relationship; $f(x)$ expresses that a certain quantity is made up of some modifications of x, without saying what they are. It operates generally upon the form $y = f(x)$. One leading and important enquiry is to find the symbolical expression, when the variable x receives a certain increment h, and becomes $f(x + h)$. This gives birth to distinct theorems, called Taylor's Theorem, Maclaurin's Theorem, Lagrange's and Laplace's Theorems, and conducts to the Differential Calculus.

10. Algebra shows the equivalence of different operations; and thereby gives the means of resolving the one into the other.

This is to extend the propositions of Arithmetic. By studying the Algebraic forms, we find that the square of a sum $(a + b)$ is equivalent to the squares of the separate factors added to twice their product $(a^2 + b^2 + 2\,a\,b)$; no matter what the numbers are.

11. The use of signs of operations readily leads to ex-

pressions not interpretable into any actual facts; and the distinctive business of Algebra is to define and justify all its combinations.

Subtraction in Arithmetic cannot be performed without something to subtract from; the Algebraic sign —, may be prefixed to a number irrespective of this fact. Not only so, but the number so qualified may be formally subjected to all the operations performable upon real numbers. We may suppose two negative quantities multiplied together, a process not to be realized in fact. There is a still greater departure from possibility in placing a negative quantity under the sign for extracting the square root, $\sqrt{-1}$, $\sqrt{-a}$.

It is necessary to qualify the rules for the cardinal operations of Arithmetic, in their extension to Algebraic quantities, by explaining the conditions of the use of the signs:—to lay down and demonstrate such rules as 'minus multiplied by plus gives minus;' 'minus multiplied by minus gives plus.' Although the demonstration of such rules is a matter for logical discussion, we do not enter upon it here Mathematicians usually satisfy themselves in all such cases by an appeal to the verification of experience; to which they append some form of deductive proof. But deductive proofs in such matters would never be trusted by themselves, or in the absence of verifications. Thus, 'minus multiplied by minus makes plus,' is shown by manipulating the product of two differences as $a - b$, by $c - d$; where it is seen that only by this rule can we obtain a correct result.

12. The highest form of the Algebraical problem is the Resolution of Equations.

This contains all the preceding processes, and applies them in an advantageous manner to disentangle complicated relationships of numbers.

In an Equation, two expressions known to be equal are placed against one another; as—

$$13\,x + 2\,a - b = 6\,x - c.$$

By applying the fundamental axioms of equality, and a few of the convenient derivatives from them (the differences of equals are equal, equal multiples and equal quotients of equals are equal, the squares, square roots, &c., of equals are equal), the equation may be so manipulated that there may stand, at last, on one side, the quantity x (whose value is desired), and, on the other, a function made up of a, b, c, to the exclusion of x;

strict equality being preserved at every step of the transforming operation. No logical difficulties are involved in this refined and powerful machinery; while it may be quoted as happily exemplifying the intervention of the axioms and derivative propositions of equality.

Geometry.

13. Some of the more difficult logical questions arising out of Geometry—those relating to the Definitions, Axioms, and Postulates—have been already considered; it remains to advert to the *order* of *topics.*

Every science reposes alike on Definitions and on Axioms; which accordingly are stated at the outset. Generally speaking, the Definitions come first, the Axioms next. But the Axioms of Geometry may be supposed already given, as the indispensible basis of Arithmetic, and, therefore, need only to be recited along with any corollaries or derivatives especially required in Geometry.

It would be advisable to state first of all the concrete basis of Geometry—to give the notions attainable only from concrete experience. These have been already enumerated. To make a broad separation between these ultimate indefinable notions, and the properly definable, the expositor might interpose the review of the Axioms, especially dwelling upon their inductive character, and drawing the line between the fundamental and the derivative. At this stage the teacher should allow himself the fullest latitude of concrete illustration.

Next would follow the remaining Definitions in order of derivation or dependence. Frequently, corollaries are given also; but these are not proper, or mediate, inferences; they are mere equivalents of the definition, not to be denied without self-contradiction. Such are, 'only one straight line can be drawn between two points;' 'all right angles are equal.' No mediate inference can be drawn from a Definition without the introduction of an axiom; a truly deductive process, amounting to a theorem.

Euclid's three first propositions are problems or constructions. The first theorem is the real start of the Geometrical concatenation; namely, the fourth proposition—establishing the equality throughout of the two triangles having two sides and the included angle equal. This is the sole basis of geometrical *comparison*, the commencing stride that renders possible all the subsequent assertions as to the equality and

inequality of triangles, parallelograms, &c. The proof of the proposition is peculiar; only once again (I. 8) is the same operation made use of; namely, the ideal placing of the one triangle upon the other. Here, in fact, we have an inevitable appeal to experiment or trial in the concrete; just as in the definitions and the axioms, we must take our first lessons from the manipulation of actual objects. Euclid, by his mode of stating the demonstration, professedly goes through a process of pure deduction, all the time that he requires us to conceive an experimental proof. He appears to be using merely an illustration in the concrete; but if his readers had not made actual experiments of the kind indicated, (doubtless the same experiments as gave the original notions of line, angle and surface) they could not be convinced by the reasoning in the demonstration.

If apparently a proposition be proved without appealing to an axiom (either directly or indirectly), shows that the proposition cannot be real; the subject and predicate must be identical. The proof rests solely on definitions; but a definition by itself cannot advance us a step. The proposition must, in fact, be a mere equivalent of the notions of line, angle, surface, equality—a fact apparent in the operation of understanding these notions. It is implicated in the experience requisite for mastering the indefinable elements of Geometry; and should be rested purely on the basis of experience.*

The 5th proposition is what really constitutes Euclid's first demonstration by a genuine process of reasoning. In it, there is a legitimate deduction from the axioms common to all mathematics, conjoined with the *induction*, falsely called a demonstration, given as the 4th proposition. The axioms applied are, the proper axiom, 'the sums of equals are equal,' and the derivative, 'the differences of equals are equal.'

14. It is the characteristic of elementary Geometry to maintain the concrete reference to diagrams, which gives the subject to appearance, but only to appearance, an inductive or experimental character.

* Mr. CHALLIS remarks, on the Fourth Proposition, that the proof rests on no previous proposition, and appeals only to the simplest conceptions of space. 'This proposition is proved by the principle of *superposition*, neither requiring, nor admitting of, any other direct proof.' A casual observation of Mr. De Morgan's is well exemplified by Euclid's attempt to demonstrate this fundamental assumption—'the Conversion of identity by help of a syllogism is *reasoning in a circle*.'

All symbolical reasonings are liable to mistake. Not to speak of the slips that the reasoner himself may commit unknowingly, there is often a failure of adaptation between the laws of the symbols and the laws of the matter they are applied to. For this the remedy is the constant verification of the results. Now, in Geometry, an actual figure is always before the eyes, and the effect of every construction and every step of reasoning is judged of by actual inspection. When the direction is given to join the opposite angles of a quadrilateral, there is apparent to the glance the division of the figure into two triangles. For the most part, Euclid offers no other proof of this class of consequences. Sometimes he applies the *reductio ad absurdum* in such cases, as in the proof that the tangent to a circle falls without the circle.

So long as Geometry is discussed in the concrete, or by naming lines, angles, circles, the mind must conceive them in the concrete, which would be impracticable without the help of diagrams. In Algebraic Geometry, the concrete form is exchanged for numerical equivalents, to be manipulated according to the laws of operation in Arithmetic or Algebra; a rectangle is no longer a fact of space but a product of numbers or symbols; a curve is an equation. The student is cautioned by Mr. De Morgan that, although the names 'square' and 'cube' are transferred to Algebraic quantities, as a^2, a^3, the names mean different things from geometrical squares and cubes.

Algebraic Geometry.

15. The expression of Geometrical quantities by Algebra, while depriving the mind of the assistance of the diagrams, greatly enlarges the power of demonstration and inference.

Compare Euclid's 2nd book with the same propositions algebraically rendered; the one is laborious, the other comparatively easy.

The great device of Descartes, for expressing curves algebraically by co-ordinates whose relation in each case could be stated in a formula, opened up a new field of mathematics. The conic sections became comparatively easy; and curves of a still higher order that would have baffled common geometry were brought under investigation. The method was also an essential prelude to the Differential calculus.

16. Algebraic Geometry furnishes specific rules for the embodiment and for the interpretation of formulæ. The rest is pure algebra.

It is easy to embody a rectangle, in terms of the sides; an algebraic product is sufficient for the purpose. Angles may be expressed by their proportion to the circle, that is by their subtended arc, and also by their sines, tangents, &c. Curves are given by co-ordinates on the Cartesian plan. The rules of embodiment are also the rules of interpretation. But as there is frequent danger of overstepping geometrical conditions by algebraical operations, the interpretation must be continually verified. Mathematics is the slipperiest of sciences; its analytical processes are full of pitfalls; but luckily, it is the easiest to keep right by verification. The arithmetical symbols 0 and 1 are used with a latitude that makes them ambiguous, unless, for each case, there is a distinct understanding made and adhered to.

The Higher Calculus.

17. The representation of continuous quantity, by means of numbers, in certain cases, fails to give a neat or definite result.

Continuous quantity, as exemplified in lines and in motions, must be supposed to be broken up into equal portions in order to be expressed numerically, and thereby to be made the subject of arithmetical computation. In certain instances, the division cannot be made without a remainder. Hence arises a peculiar difficulty.

In vulgar fractions, first emerges the peculiar case of *incommensurable* quantities, that is, quantities that have no common measure. In Geometry, the side and diagonal of a square are incommensurable; if the side be divided into equal divisions, no matter how many, these divisions will not apply to the diagonal without a remainder. So with the diameter and the circumference of a circle.

18. The solution of Incommensurables, and the accommodation of numbers to continuous quantities generally, can only be *approximate*. A variety of modes have been devised, at bottom the same, for working out the approximation.

Mathematicians long struggled to evade the difficulty before acknowledging the true character of the solution. A great number of persons refused to believe that the diameter and circumference of a circle would for ever remain incommensurable.

Euclid's definition of proportionals is deservedly admired for its ingenuity in endeavouring to comprise incommensurable quantities; but it is not satisfactory. A competent judge (De Morgan) remarks, first, the want of obvious connexion between it and the ordinary well-established ideas of proportion; secondly, its involving an idea of infinity; and lastly, the apparent unlikelihood that any quantities exist capable of satisfying the definition. The difficulties can be met only by the method of approximation, on which is based the whole structure of the higher or transcendental analysis.

The first application of the approximate methods was to the quadrature of the circle, as given in Euclid. The process there given is commonly called the method of Exhaustions. The gist of the matter lies in the proposition—'A circle being given, two similar polygons may be found, the one described about the circle the other inscribed within it, such as shall differ by a space *less than any given space*.' These last words give the idea running through all the processes, named the Theory of Limits, Prime and Ultimate Ratios, Infinitesimal Quantities. A curve line can never be a straight line, but by diminishing the arc, the approximation of the two increases, until at last we pass not only beyond any sensible error, but beyond any error that may be assigned. Thus an arc may be said to be the *limit* of its chord; the area of a circle may be said to be identical with an inscribed, or a described, polygon of an infinite number of sides. Now as the polygon consists of a series of triangles with a common apex in the centre, the area of the polygon is equal to half the product of the radius and the sum of the bases, or chords; and by diminishing these chords without limit, they become identical with the circumference of the circle.

The method of Exhaustions was applied by Archimedes to the quadrature of the parabola, and to the solid measurement of the cone, sphere, and cylinder; all which give neat solutions, or expressions in finite terms. The subsequent developments were left for modern times, after the discovery of algebra; and they advanced as algebra and its applications to geometry advanced. The Fluxions of Newton and the Differential Calculus of Leibnitz were the great algebraic embodiments. These methods contained a new order of quantities, called Fluxions (by Newton) and Differential Co-efficients (by Leibnitz), formed from ordinary quantities on considerations growing out of the method of Limits, and resolved back again on the same laws. The quantities once created, the operations

were treated as pure algebra, and mathematicians left them to be justified by their results, rarely attempting to render a reason for the assumptions lurking under them. Hence, such attacks upon the system as Berkeley's famous sarcasm, that the fluxional calculus operated upon the ghosts of departed quantities. The neglect to assign the true basis of the calculus, and the treating it from first to last as a pure algebraic assumption, culminated in Lagrange; against whom Whewell and De Morgan have reclaimed, and have provided the necessary reconciliation of the algebra with the conditions of the various problems to be solved; showing that approximation and compromise must be held as essential to the operation.

CHAPTER II.

LOGIC OF PHYSICS.

1. It has been seen (Introduction) that the branch of science termed Natural Philosophy or PHYSICS is divided into two parts—*Molar Physics* and *Molecular Physics*.

The aggregate called Natural Philosophy scarcely admits of definition, until separated into distinct departments—*Molar Physics*, or Motion in Mass, and *Molecular Physics*, or Motion in Molecule.

The Physics of Masses, *Molar Physics*, includes the phenomena of Motion and Force, as belonging to bodies in the aggregate. Such are the phenomena of planetary motions, of falling bodies, rivers, winds, &c.

The Physics of Molecules, *Molecular Physics*, relates to the motions and forces operating between particles or molecules, these being of a degree of minuteness far beyond the reach of the human senses. The phenomena representing such notions and forces, are the Aggregations into masses; Cohesions and Adhesions generally; Heat; Electricity; Light. Reservation is made of the peculiar form of molecular force, called Chemical force, as having a character and consequences peculiar to itself.

MOLAR PHYSICS.

Divisions of the Subject.

2. The Abstract Branches, comprising Motion and Force in general, and susceptible of Deductive and Mathematical treatment are these:—

Mathematics of *Motion* —*Kinematics.*
Forces (1) in Equilibrio —*Statics.*
Forces (2) causing Motion—*Dynamics.*

The Concrete Branches are—

Mechanic Powers and Solid Machinery.
Hydrostatics and Hydro-dynamics.
Aerostatics and Pneumatics.
Acoustics.
Astronomy.

Notions of Molar Physics.

3. In Physics, are pre-supposed the Notions (as well as the Propositions) of Mathematics. Only those special to the science are here reviewed.

Motion—Rest.—This antithetic couple is the fundamental conception of Physics, and is probably an ultimate experience of the human mind. We obtain the idea of Movement by a peculiar employment of our active energies, assisted by sensation. We also obtain a knowledge of the varieties of movement—quick, slow, uniform, varying, straight, curved, continuous, reciprocating, pendulous, wave-like, &c. The modes that depend upon degree, or *Velocity*, are part of the ultimate experience of motion as such; those characterized by shape or *Form* have a property common to mere extension.

Force.—This is without doubt the most fundamental notion of the human mind; in the order of evolution, it concurs with, if it is not prior to, both motion and extension. It cannot be defined except in the mode peculiar to ultimate notions. The feeling that we have when we expend muscular energy, in resisting or in causing movement, is unique and irresolvable.

Inertia, Resistance, Momentum.—These names designate our experience of force from the objective side, or as embodied in the things of the object world. The occasion of calling forth our feeling of energy when referred to an external fact is Resistance, Inertness, Momentum, or External Force—all signi-

fying the same thing. This great fact must be learnt, in the first instance, by each one's separate experience; the best mode of scientifically expressing it is a matter for discussion.

Matter is Extension, coupled with *Force* or *Inertia*. Anything extended and at the same time possessing force, either to resist or to impart motion is Material.

Mass, Density, Solidity, are derived notions; they are obtained by putting together Force and Extension or Volume. The *Mass* is the collective Force of a body, shown by its degree of Resistance, and also by the amount of Resistance it can overcome when moving at a given rate. The *Density* is the degree of space concentration; a given power of resistance, with a smaller bulk or volume, is a greater *Density*. *Solidity*, when not signifying the solid state of matter generally, as opposed to liquid or gas, is another name for Density.

Impact is a phenomenon expressed by means of Space or Extension, Motion, and Force. It is one mode of imparting visible or kinetic energy, and is a test or measure of Force.

Attraction is definable by Extension, Motion, and Force. It is a mode of communicating Force, distinct from Impact, and in some respects simpler. Among its specific examples are Gravity, Cohesion, Adhesion, Magnetism, Electrical Attraction, (Chemical Attraction).

Repulsion is definable by reference to the same fundamental notions. It also is a mode of imparting or redistributing force, and differs from Attraction only in the way that it changes the relative situation of the masses concerned. It is exemplified in the Expansive energy of Gases in their ordinary state, in the Expansion of Liquids and Solids from rise of temperature and after compression (called Elasticity). The Polar Forces—Magnetism, Electricity, &c., exercise, along with Attraction, a counterpart Repulsion.

By still farther combining these primary notions, we obtain —Equilibrium, Composition and Resolution, Resultant, Virtual Velocity, Centripetal, Centrifugal, Tangential force, Projectile.

To *Mechanics* belong Specific Gravity, Centre of Gravity, Stability, Oscillation, Rotation, Percussion, Friction, Mechanic Power, Machine, Work.

In *Hydrostatics*, occur Liquid, Liquid Pressure, Liquid Level, Displacement, Flotation, Column of liquid.

In *Hydro-dynamics*, Liquid Motions, Efflux, Discharge, Liquid Waves.

In *Aerostatics* and *Pneumatics*, Air, Atmosphere, Expansion of Gases, Flow of Gases, Undulations, Atmospheric pressure.

In *Acoustics*, Sound, Pitch, Timber, Vibrations, Noise; Note, Echo, Harmony.

In *Astronomy*, Sun, Planet, Satellite, Comet, Aerolite, Bolid, Star, Nebula, Orbit, Ecliptic, Year, Month, Day, Eclipse, Transit, Parallax, Aberration, Right Ascension, Declination, Eccentricity, Node, Apside, Perihelion, Perturbation, Libration, Precession, Nutation, Tides.

Propositions of Molar Physics.

4. These are of the following classes:—(1) The Inductions of Force and Motion; (2) The Deductive Propria asserting the quantitative relationships of Motion and Force; (3) Empirical laws of the concrete phenomena.

(1) The great Inductions, commonly called the Laws of Motion, are the axioms of the science. These will be considered afterwards. They are all quantitative in their expression. Another fundamental Induction is the Law of Gravity.

(2) The science being pre-eminently Deductive, its propositions are for the most part deductions from the axioms. Such are—the propositions of the Composition and Resolution of Motions and Forces; the proposition called the 'law of Areas;' the principle of the Mechanic Powers; the principles of the pendulum; the law of liquid pressure; the principle that connects fluid motion with fluid support; the laws of the propagation and the reflection of sound.

All these matters are stated in the form of real propositions, which, however, may be deduced from the axioms or inductions of the science applied to the particular cases as scientifically defined. For example, the law of fluid pressure is a proposition to this effect. 'At any point in a fluid at rest, the pressure is equal in all directions;' the *subject* of the proposition supposes a fluid at rest, a point taken in it, and consideration given to the pressure; the *predicate* is 'equality in all directions.' The proof is deductive, and ultimately rests on the axioms of motion and force, together with the definition of fluidity, although the proximate majors are the propositions of the Composition of Forces.

Subsidiary to the working out of the science are the propositions expressing the *quantities* of motion, force, &c., existing in actual things. Thus, besides the Law of Gravity, we have a statement of the numerical amount of gravity at the earth's surface; also the relative gravities of different solids and fluids. These numerical propositions are called the *data*.

constants, or *co-efficients* of the science, and are ascertained by observation and experiment.

(3) There are certain *empirical laws* obtained by observation or experiment. Such are the laws of the Strength of Materials (to some extent Deductive), the laws of Friction, the Motion of Projectiles (partly Deductive), the Flow of Rivers, the Spouting of Liquids, the Compression of Liquids and of Gases, the Diffusion of Sound, the action of Vibrating Strings, &c. These are all real propositions; they are in their nature *propria*, or deducible from ultimate principles; but, in the present state of knowledge, they must be gained by direct experiment.

Definitions of Molar Physics.

5. As in Mathematics, so in Physics, there are certain properties that are ultimate, and incommunicable by language; being known by each one's independent experience. Nevertheless, it is open to us to consider the best mode of generalizing and stating this experience.

The facts named Motion, Force, Matter, are understood only by our concrete experience of the things denoted by the names. But our crude observations may be rectified by more careful comparisons, and may be reduced under precise general statements. Moreover, as in Mathematics, we may select the *aspect* most suitable as a point of departure for our deductive reasonings.

Definition of Motion.—Of the fact of motion no knowledge can be imparted; there is nothing simpler to express it by: 'change of place' is not more intelligible than 'motion.' We must assume that each one understands motion both generically, and in its degrees (capable of numerical statement); and also in such simpler modes as straight or divergent. The more complex movements are then definable. *Velocity* means degree of motion. The only thing needing to be expressed formally is the *measure* of Motion or Velocity with reference to Space and to Time; these last-named elements being presupposed as themselves intelligible.

Matter, Force, Inertia. These are three names for substantially the same fact. At the bottom, there is but one experience, although varied in the circumstances, namely, the experience of putting forth muscular energy in causing or in resisting movement. To this experience we give the names Force and Matter, which are not two things but one thing;

of which Inertia is merely another expression. It is pure tautology to define one of these terms by the others; matter is nothing except as giving the experience called also force; force is only revealed by matter moving, or obstructing movement.

Matter, however, affects us in other ways than by the muscular feeling of resistance or of expended energy. It is always extended, and in most cases visible, and also tangible. Are we not, then, to include these facts in the definition? No, and for these reasons:—(1) Extension is not confined to matter; it belongs also to empty space; therefore, though a predicate of all matter, extension is not the exclusive characteristic of matter. (2) Visibility and Tangibility belong to many kinds of matter, but not to all matter; hence, these properties cannot be the defining characters of matter in general, or of all matter; they are to be reserved as properties of the kinds of matter wherein they occur; solids and liquids, for example. Accordingly, the only fact occurring in all matter is the fact expressed by resistance, force, or inertia; all which are names for a single phenomenon. This phenomenon, when fully examined, and generalized to the utmost, has two different aspects, which we may separate in expression, but cannot separate in nature; the one is the resistance to movement by bodies, whether at rest or in motion, and the other, the imparting of movement or momentum by being in motion. The first aspect of resistance is the more popular meaning of inertia; the second aspect, the imparting of movement, is the popular view of force; but in the scientific consideration of the subject, these are but one property.

The definition of Matter and of Inertia, or Inert substance, is, therefore, but one. It generalizes our familiar experiences of resisting motion and of communicating motion, which always concur in the same thing. Fully expressed, it amounts to the statement given in the First Law of Motion. We are entitled to lay down as the fundamental or defining attribute of matter, in whose absence matter is not, that if once at rest it remains at rest, and if once in motion, it continues moving in a straight line. To put it from rest to motion, moving power must be employed; to arrest its course, matter, either in motion or at rest, must be opposed to it. All this is involved in the very meaning of matter. We cannot divide these expressions, and assign one as the defining mark of matter, and the other as a predicate distinct from the definition. No one has ever succeeded in constituting a REAL proposition out of these properties. The appearance of a real

proposition could be given only by assuming as the meaning of matter the imperfect view entertained by the unenlightened mind (which, owing to adverse appearances and imperfect knowledge, does not fully recognize the persistence of moving matter), and giving as the predicate the scientifically rectified generalization of matter; but when this generalization is attained, it is wholly embodied in the definition of matter; it cannot furnish one fact as a defining property and reserve another as a predicate. There is a *definition* of Inertia; there is no *law*.

Thus, then, the persistence in a state of rest or in a state of uniform rectilineal motion, is the meaning of Inertia, and of Matter in general; in which meaning there is an unavoidable implication of active resistance, and active communication of motion. The difficulty is to find an expression to comprehend all these aspects of one indivisible property. Matter at rest operates at one time in dead resistance, at another time in using up force by itself passing into motion; matter in motion may resist movement, or it may generate movement; but, these are not a plurality of properties; we cannot suppose one of them separated from the others. The definition employs plurality of phrases in order to encompass a unity.

Matter and Inertia being thus defined by one stroke, *Force* is merely another reference to the same fact. Inert Matter in motion is the most characteristic expression or aspect of Force, and is adopted as its numerical measure; but we cannot exclude from the idea the consideration of matter at rest. In measuring force by moving matter, we mean matter transferred from rest to motion, or from one rate of motion to a quicker; this is force as generated. Again, the force is manifested in the abatement of the motion, in reducing bodies to the state of rest; this is force as expended.

As there is but one fact underlying Matter, Inertia, Force, so there is but one measure. A larger quantity of matter, or inertia, is the same as a larger expenditure of force to change the matter from rest to a given pace of motion. The ultimate measure is the human consciousness of expended energy. There is a palpable impropriety in the expression, given as a law,—'The amount of inertia increases with the quantity of matter;' the two properties stated are but one fact.

To sum up. Each person by their own experience must become acquainted with the concrete examples of matter and force. A comparison of all varieties of the phenomenon reveals the presence of a common feature, at bottom one and

indivisible, but variously manifested as resistance, as a source of movement—as persistence in rest or in uniform rectilineal movement. To this many-sided unity, we give the names Matter, Inertia, Force, which have a common definition and a common estimate. The word Matter is the concrete name, while Inertia and Force are the asbtractions for what is common to all matter.

Mass, Density.—*Mass* is the quantity of matter, measured in the mode already described, namely, by the expenditure requisite to change the body's state by a given amount. When the Mass is given, and also the volume, or bulk, we obtain the *Density*. Volume and Mass rightly precede Density, in order of definition. Messrs Thomson and Tait make Density precede Mass.

Momentum means quantity of motion; its measure is the mass multiplied by the velocity. The unit quantity of motion is some unit of mass, multiplied by a unit of velocity. Mass is usually estimated by *weight*, but this is to anticipate the consideration of gravity, which should be excluded from the elementary definitions of motion, matter, and force.

The defining of the notions following on these—Impact, Attraction, Repulsion, Gravity, Cohesion, &c.—presents no logical difficulties. They are all derivative notions, their elements being the above named primary notions coupled with those of mathematics; and they are defined as such, although concrete examples may be given to aid the understanding of the more difficult abstractions.

Thus, *Impact* is the transfer of force from one body to another by momentary concourse; the direction communicated being the direction possessed. *Attraction* is the continued generation of moving force shown in the mutual approach of two bodies; *Repulsion* is the generation of force leading to the mutual recess of bodies. *Gravity* is the attraction inherent, persistent, and unchangeable in all matter, being proportioned to the mass, and extending to all distances, at a uniform rate of decrease.

Axioms of Molar Physics.

6. The chief axioms of the science are usually stated under the title—Laws of Motion.

In the statement of these laws verbal and real propositions are confounded.

Newton's First Law—'Every body perseveres in its state of rest or of uniform rectilineal motion, unless compelled to change that state by impressed forces'—is merely the full expansion of the definition of matter, inertia, or body. It no doubt expresses more than the vague unscientific notion of matter, but no more than is absolutely inseparable from matter. It is a verbal and not a real proposition—a definition disguised as a proposition. 'Body' *means* what Newton predicates of it; withdraw from 'body' all that the law affirms and implies, and there would be nothing left. If a body did not persevere in its state of rest or motion, until disturbed by another force, it would not possess the most elementary conception that we can form of body, the property of resistance. Of the various modes of exhausting the aspects of body, matter, inertia, force, it may be doubted whether Newton's is the most felicitous. At all events, the attempt would succeed better, if the statement were in the only legitimate guise—a Definition.

Newton's Second Law is—'Change of Motion is proportional to the impressed force, and takes place in the direction of that force.' This law assumes the fact of the communication or transfer of motion, and affirms, although not in the best manner, the quantitative equivalence of the motion given with that received.

The Third Law is—'To every action there is always an equal and contrary re-action; or the mutual actions of any two bodies are always equal and oppositely directed.' More shortly expressed thus—'Action and Reaction are equal and contrary.' Objections have often been taken to the word 'Re-action' in this law. The meaning put upon it by Newton is gathered from his own illustrations. His examples are of two classes. The first puts the case of *impact*, as in pressing a body, or in drawing it by some solid medium as a cord or a rod. There is, to say the least, great awkwardness in representing the communication of force by impact, in these terms: —'when we push a stone with the hand, the hand is pushed back by the same force as the stone is moved forward;' or 'a horse towing a boat is dragged backwards by the same force as the boat is dragged forwards.' The more natural expression is that when one moving body gives motion to another, it loses exactly the energy that it communicates; or that on the re-distribution of force or moving power nothing is lost. Now, if there be any real affirmation in the *Second* Law, it is this and nothing else.

The other class of examples given by Newton comprises a distinct case, and the only case that gives the appearance of propriety to the word 're-action.' It is the communication of movement by distinct attraction (or repulsion). When one body attracts a second, the second equally attracts the first; the attractions are mutual and equal; the momenta produced are exactly the same in each. This is a fact of great importance in nature and deserves to be singled out; indeed, it is the only case of communicated momentum where the result is unaffected by disturbances that interfere with exact calculations.

Now this is to be regarded as a separate induction. It is fully consistent with the principle of the conservation of energy, under re-distribution, as represented by impact, and has some inherent probability in its favour, but still requires the confirmation of experience. Ingenious reasons might be given, why no other result should arise, but there is no infallible deductive cogency in applying the Law of Conservation, founded on impact, to the equality of mutual attractions.

Searching thus through the three Laws of Motion, we encounter only one principle—the principle of Conservation of Force under re-distribution. The second law has no meaning but this. That 'change of motion is proportional to the impressed force' with difficulty escapes from being a verbal proposition, for there is no other measure of force but 'change of motion,' imparted, or impartible movement. The assertion would have no reality but for the circumstance that a moving body encounters another body and changes the state of that other body—urging it to move or arresting its movement. This is a supposition not made in the bare definition of force; and, therefore, we do something more than repeat the definition, when we affirm that the force imparted to the second body is lost to the first. Now, this is all that the Third Law contains; only that law brings into prominence the distinct case of force arising by attraction or repulsion at a distance. Discarding, therefore, the present First Law, as being but the definition of Inertia, we may condense the second and third into a single statement declaring the Conservation motive Energy, under re-distribution, whether by impact, or by attraction or repulsion. This is the one *axiom* of the Science; its foundations are inductive. It is a partial statement, applicable to *molar* forces, of the all-comprehending law of the Conservation of Force. Indeed, in the limitation to molar

force, the principle is not strictly true; it is true with regard to attractions and repulsions, and hence in Astronomy no error is committed in applying it; it is not true of impacts; there is always force lost in a mechanical collision, or in the transfer by machinery; the lost mechanical energy re-appearing as molecular vibration or heat.

Newton's second law has been considered as a way of providing for the case of the communication of movement to a body already moving in some other direction. A force impelling in any direction will accomplish its full effect in that direction, even although the body should be already in motion in some different direction; as when a ship sailing in a westerly current is propelled by a north wind. This is the foundation of the law of composition of Motion and Force, but it is still only an application of the principle of Conservation of Energy under re-distribution. Direction as well as amount are included in the principle; a body moving in a certain direction and imparting motion, imparts it in its own direction, and in no other. Before affirming the Law of Conservation in its full generality, we are bound to verify it for this case as well as for mutual attraction; it has been verified, and is affirmed accordingly.

The so-called 'Principle of Virtual Velocities' is a hypothetical expression of the Law of Conservation suited to various mechanical applications, such as the demonstration of the mechanic powers. We cannot prove the statical proposition of the lever, without supposing it to move. Dynamically the law of the mechanical powers is the only one consistent with the Conservation of Force; and the dynamical proof is given as the *statical* by the supposition of a very small motion.

7. The second great Induction of Molar Physics is the Law of Gravity.

The Law of Gravity associates the two distinct properties—Inertia and Gravity, and declares the one to be proportioned to the other, throughout all varieties of matter. The Law is sufficiently expressed thus:—Every portion of matter attracts every other portion, the attraction in each being in proportion to the mass (or inertia), and inversely as the square of the distance.

This Law has been frequently referred to, in previous parts of this work, as the one unequivocal case of two co-extensive properties, constituting a proposition fully reciprocating, and convertible by simple conversion.

Our unit of force (so much inerta acting through so much space) is thus the unit of weight, say a pound, moved against gravity through the unit of space, say a foot.

Concatenation and Method of Molar Physics.

8. The branches of Molar Physics follow a Deductive arrangement. The Abstract departments are purely deductive; the Concrete unite Deduction with Experimental determinations.

The great division into *Statics* and *Dynamics*—Equilibrium and Movement—exhausts the abstract portion of the subject. These are thoroughly mathematical in their structure; the propositions and demonstrations are worked out according to Geometry, Algebra, or the higher Calculus, respectively. A preliminary mathematical department is constituted, which has been termed 'Kinematics,' containing propositions that assume only the fact of Motion, together with mathematical elements. The Composition and Resolution of Motions, under every possible variety of complication, are mathematically developed under this branch; it being also applicable to Optics. The theorems are then found to be transferable to Statical and to Dynamical Problems, which regard Motion as the result and the essential fact of Force, whose full expression includes as factors the Velocity and Mass.

The Concrete Branches are:—I. The *Mechanic Powers*, and *Machinery* generally (fluid action not included). Here there is an application of the deductive laws, but these have to be modified by the molecular structure of bodies; and the modifications are ascertained experimentally. The laws of friction, of stress and strain, of molecular transfer in impacts, &c., are the subject of experiment almost exclusively. Where deduction is applied, it must be submitted at every step to experimental confirmation.

II. *Hydrostatics* and *Hydro-Dynamics*, or abstract Statics and Dynamics applied to Liquids. There is here also the employment of experiment to find out the modifications of dynamical laws due to the molecular structure of liquids. There is a farther use of experiment, in aid of the deductive process itself, which is apt to be foiled by the complications of fluid mobility.

III. *Aerostatics* and *Pneumatics* comprise the treatment of gaseous bodies, to which the foregoing remarks also apply.

IV. *Acoustics* treats of vibrations of the air and other bodies,

constituting the agency of Sound. Here we have the transition from the molar to the molecular; but the mode of dealing with the phenomenon (through the similitude of pendulous and wave motions) has close alliances with the preceding molar branches. In this department, however, experiment predominates over deduction.

V. *Astronomy* might be taken either first or last among the Concrete branches. It departs the least from abstract Statics and Dynamics; which is owing to the purity of the gravitating force; there being no friction and, in the celestial region, no resistance. It is deductive throughout; yet, owing to the great mathematical difficulties, the deductions must be checked by continual observation; while to observation alone we owe the knowledge of the co-efficients or constants.

In Astronomy, there are various problems that draw upon the other concrete branches of molar physics, and even upon molecular physics; so that the position of priority among the concrete branches has to be qualified. The tides, the physical constitution of the sun and the planets, the theory of solar and planetary heat and light—are examples of these far-branching portions of the subject.

MOLECULAR PHYSICS.

9. In Molecular Physics, the phenomena have reference to the action of the component molecules of matter.

The chief subjects are—

Molecular Attractions—Cohesion, &c.,
Heat,
Light,
Electricity.

The primary assumption, axiom, or induction of Molecular Physics is to the effect that the masses of matter are composed of small particles, atoms, or molecules, attracting or repelling each other in various modes, and possessing intestine motions. This is a real proposition respecting matter, and not a mere repetition of its defining property—Inertia. It is pre-eminently hypothetical in its character; that is, the evidence for it is only the suitability to express the phenomena open to the senses; as, for example, the solid, liquid, and gaseous forms of bodies, the heat or temperature of bodies, luminous and electrical effects.

Notions of Molecular Physics.

Molecule, Atom.—It is known as a fact that every kind of matter is made up of very minute portions, called atoms or molecules; the limit of minuteness being hitherto unascertained. By supposing attractions and repulsions between the atoms, we can represent the varieties of solid, liquid, and gas, as well as the imponderable forces—heat, &c. The phenomena, however, require that there should be different orders of atoms or molecules; the ultimate atoms being grouped into complex atoms, and those again, perhaps, into still higher compounds. Thus, the Cohesion atom, the Heat atom, the Chemical atoms, the Solution or Diffusion atom, are all hypothetically distinct, the assumptions being varied to suit the appearances. The definition of the atom or molecule,* therefore, is hypothetical and fluctuating; the only constant assumption is a very minute element gifted with attractions and repulsions, by which is brought about the aggregation into masses.

MOLECULAR ATTRACTIONS—PROPERTIES OF MATTER. Numerous important notions arise out of this department of Physics, which discusses the various modes of aggregation of material masses, and their causes, real or hypothetical.

Solid, Liquid, Gas.—These names for the three states of matter, have already occurred under Molar Physics, and must there have been defined up to a certain point. The exhaustive definition of the various forms of solidity falls under Molecular Physics. I shall indicate, for ulterior ends, what seems the best arrangement or succession of the properties of Solids.

Crystal.—Antithesis of *amorphous*. The crystal is not difficult to define. The common fact is a regular and constant geometric form as determined by the angles of the faces or boundary planes. A substance, for example, always found in cubes, or with right-angled solid angles, is a crystal; a substance that has no regular or constant form is amorphous; such is a cinder. Subsidiary to the main idea, are the notions —*face, axis, nucleus, cleavage, fracture*—and the several systems

* Although the adjective 'molecular' is used in the broad contrast with the molar, while the substantive 'molecule' also conforms to the usage, a more specific meaning has lately been attached to the molecule, in contradistinction to the 'atom.' An atom is supposed to be chemically indivisible; a molecule is the smallest combination believed to exist separately. There is a hydrogen *atom* represented by H; but the hydrogen *molecule* is H H, or H_2. The molecule of Phosphorus and of Arsenic is each composed of *four* atoms. All this belongs to the hypothetical part of Chemical Combination.

of crystals—Tesseral, Tetragonal, &c.; also Isomorphism, Dimorphism, Allotropy.

Hard, Elastic, Tenacious, Ductile, Malleable. These are names for a series of important attributes of solid bodies, to which there is a corresponding series of contrasting properties —*soft* or *flexible, inelastic, brittle, inflexible, inductile* or *unmalleable.* They are mostly distinct properties, although to some extent related. They are all strictly definable, and measurable in amount or degree by given tests. Hardness is the resistance to change of form, as by scratching or dinting; Elasticity is the rebound from compression. Tenacity is opposed to being pulled asunder. Ductility is tenacity under the process of being drawn out into wire; if the hammer is employed, the substance is called Malleable.

Viscosity is a softness approaching to liquidity. 'All bodies capable of having their form indefinitely altered, and resisting the change with a force proportioned to the alteration, are called Viscous Bodies.' (J. Clerk Maxwell).

Cohesion (Homogeneous attraction). Definable as the mutual attraction of particles of the same substance, as iron, flint, or ice. The crystalline structure, hardness, and other qualities in the previous enumeration, may be expressed as different degrees and modes of cohesive energy. Cohesion is therefore the hypothetical summary of the properties just named; and its modes are to be accommodated to represent these with accuracy. A crystal must have one mode of cohesion, a lump of clay, a different mode. The limits of cohesion are small; two pieces of plate glass will adhere strongly if in close contact, but will not attract one another through a sensible distance.

Adhesion (Heterogeneous attraction). A wide-ranging phenomenon. It is defined—the attraction of particles of one substance for particles of a different substance, as when glue sticks to wood, mortar to stone, water to wood, &c. Cements, Capillary action, Solution, Absorption of Gases, Alloys—all suppose this mode of action. To express the full details—which substances attract which, and with what degrees of force—requires a great many propositional statements, most conveniently given in the mineral or the chemical description of each substance. Under the present head, the general results should be presented.

Diffusion, Osmose.—These are properties extending beyond what is implied in solution, and even anticipating Chemical processes. Still, they are the immediate sequel to the preced-

ing group of phenomena. Their definition is a generalization of the phenomena brought to light by the researches of Graham.

Crystalloid, Colloid, Dialysis.—By extending the application of Osmose, Graham arrived at a distinction among bodies, expressed by the antithesis—Crystalloid and Colloid, whose definition is in the highest degree pregnant with important attributes. (1) The colloid state is a mode of the anti-crystalline or amorphous modification of matter. (2) The colloids are inert chemically, they are not powerful as acids or bases. (3) In their own form, they have peculiar powers; as soft and semi-liquid they allow other substances to diffuse in them. (4) Still more important is their *instability*, their readiness to pass into change, and gradually to sink down towards the deadness and fixity of the crystal; during which process they are sources of molecular power. These two last peculiarities fit them to play a part in living structures, into which they enter largely as constituents (albumen, fibrine, starch, &c., are colloids). (5) Colloids, while permeable by bodies of the crystalloid class, as salt and sugar, are impermeable to each other; a most important law, on which Graham has founded his method of *Dialysis*, and which is the explanation of many interesting phenomena.

Effusion, Diffusion, and *Transpiration* (of gases).—These are the phenomena parallel to the foregoing as manifested in gases; they have a modified definition accordingly.

Such is an orderly statement of the great leading notions of the initial branch of Molecular Physics. They all demand strict definition, and a separation of defining properties from predicated properties, according to the best logical method. Descending into the very depths of molecular action, they unavoidably anticipate other parts of molecular physics, and even of Chemistry; but this is not avoidable by any arrangement. The priority of position is justified by the circumstance that Cohesive Force is the inalienable attribute of all kinds of matter, and is the counter-force to the great total of Energy expressed by the Correlated Forces—Heat, &c. Matter is what we find it, on the one hand, through the opposing play of internal cohesions, and on the other hand through the repulsion derived from the transferable energy of the universe. It is as Heat, Electricity, and Chemical Force, that this energy *ab extra* counter-works internal cohesion; just as, in the capacity of mechanical energy, it counter-works Gravity on the great scale of molar movements.

HEAT.—The next department in order is the primary and the typical form* of molecular energy, in the great circle of Conserved or Persistent Forces. The leading notion—*Heat* itself is the only one attended with logical difficulties of definition. Properly speaking it is an ultimate, indefinable, incommunicable notion, and its essential character is *subjective.* Each of us must be referred to our own sensations of heat and cold in their different degrees, which sensations are unique and not to be confounded with any others. Nor is there any perplexity in generalizing the particulars, with a view to a comprehensive definition, as there is with matter and inertia; he that has one or a few experiences of change of temperature knows all.

The physical or *objective* counterparts of this unmistakeable subjective experience are numerous and various, and belong to strictly physical investigation. The most obvious are the increase of bulk by warmth, and the so called destruction, (more properly re-construction) of material masses. A great and protracted effort of generalization has been requisite to encompass all the manifestations of this physical correlate of a familiar feeling, and to embrace the whole in a unity of expression. Even at the present moment, the generalized unity rests upon a hypothetical assumption, true in the main fact, but uncertain in the shaping, and as yet imperfectly adapted to the multiplicity of the thermal phenomena. Heat, physically, is a mode of molecular motion, exchanging at a definite rate with mechanical movement, as well as with the other molecular modes termed Electricity and Chemical force. If we define Heat by its subjective phase, the great physical generalization is a predicate of concomitance, constituting a real proposition. If we use the subjective fact merely as a clue to the objective, and insist on making the definition objective, this property is then the defining property, from which would flow innumerable deductive attributes (*propria*); while there would be propositions (either propria or concomitants) affirming the relationships of heat to other forces, and also the material collocations or arrangements connected with the transmutation.

The notions involved in the various phenomena of Heat, give the heads of the science; they are all definable by generalization, and their elucidation needs abundant reference to facts in the concrete:—Conduction, Convection, Radiation, Reflexion, Absorption, Diathermacy, Refraction, Specific Heat, Latent Heat, Melting, Freezing, Evaporation, Condensation, Ebulli-

tion, Boiling Point, Distillation, Tension of Vapour, Dew Point, Heat of Combination, Calorific equivalents.

LIGHT.—The exact position of this subject in a strictly studied arrangement of topics is somewhat dubious. In some important points, it has a close alliance to Heat; its manifestation in a body is almost always dependent on a certain temperature. Moreover, as an influence radiating through space, it has not only great similarity to heat, but also is singularly open to mathematical treatment. Still, being as yet imperfectly understood in its reciprocation with the correlated forces, it does not stand to heat on the same footing as electrical and chemical force. But for the close and easy transition from Electricity to Chemistry, we might put Light at the end of Molecular Physics. Or, as having abstruse chemical relationships, it might succeed to Chemistry. Thus, the position actually accorded is owing to a seeming preponderance in favour of one out of several alternatives.

Light, like heat, must have a subjective definition to start with; and, in this view, it has the same freedom from ambiguity. But as Sight is a highly objective sense, we can incorporate with the subjective property the objective particulars —radiation and transmission in space—which are revealed at once to the luminous sensibility.

We may give the definition thus:—Light expresses a distinct state of mind known only to individual self-consciousness, to which state is added the objective experience of an emanation from a material body to the eye, whereby we become cognizant of the characteristic properties of matter named visible.

The subsidiary notions are the main topics of the science:—Transparent, opaque, translucent, shadow; Incidence, Refraction, Index of Refraction, Lens, Image, Reflexion, Mirror, Caustic, Focus, Colour, Spectrum, Complementary Colours, Dispersion, Chromatic Aberration, Diffraction, Rainbow, Double Refraction, Polarization, Interference, Undulatory Theory.

So far as these topics are concerned, the science of optics depends upon no extraneous source beyond Mathematics, and might have precedence of all the other subjects of molecular physics. The connexion of Light with Heat, with Electricity, and with Chemistry, would then fall under these several departments.

ELECTRICITY.—As the denotation of Electricity takes in—

Magnetism	Voltaic Electricity	Magneto-Electricity
Friction Electricity	Electro-Magnetism	Thermo-Electricity—

it is no easy matter to find an exact connotation for the general name. Two properties may be put forward: (1) Polarity, and (2) Current action. As regards the first, Polarity, there is uniform agreement in all the modes; and, moreover, the polar attribute is prominent and pervading, and imparts a destinctive character to all the phenomena. Still, in carrying out the idea, we are met by the ambiguous phenomenon, named by Faraday, Diamagnetism, a force manifested by the magnet upon heavy glass and certain other substances, but without polarity, being equal repulsion by both poles. This phenomenon, however, must be held in suspense in the meantime, and not allowed to interfere with the definition on so vital a point.

The second characteristic of the Electric Forces, is their being carried to any distance, through solid conductors, so as to discharge themselves at any point. In ordinary chemical action, as in the double decomposition of two salts, the substances must be in contact; but by an electrical arrangement, the oxidation of zinc in one vessel, may lead to the decomposition of water in another. This important point of community makes a strong alliance, although with differences, between the electric forces.

These two leading features, coupled with subjection to the great Law of Conservation, are all that can be at present brought under the connotation of Electricity as a whole. The different branches have each their special definition, attainable by the same generalizing process. Definitions are also to be provided for the subsidiary notions—Magnetic Poles, Meridian, Declination, Inclination; Electrics, Non-Electrics, Conduction, Insulation, Circuit, Induction, Charge, Discharge, Electrical tension; Electrolysis, Electrodes.

Propositions of Molecular Physics.

Axiom of Conservation of Force.—At the threshold of molecular physics, there must be provided a statement of the Law of Conservation, in all its compass, or as embracing alike the molar and the molecular forces. Although the law cannot be fully comprehended at this stage, yet some attempt should be made to exemplify its workings as Heat, as Electricity, and as Chemical force, and also to point out the mutual conversion of all the modes—molecular and molar. The law is the presiding axiom of molecular Physics, and of Chemistry, and through them reaches the domain of Physiology. It is everywhere the sufficing explanation of the origin of Force; leaving

to be investigated, the arrangements, situations, or circumstances, attending on the manifestation of force in each particular case.

Other propositions of Molecular Physics.—The various notions or defining properties being clearly characterized, we may readily ascertain what class of predicates usually go with them so as to constitute the real propositions of the science. Thus, with reference to the first department—*Molecular Attractions*, or the Properties of Matter, from which are excluded whatever comes under Heat, Electricity, and Chemistry—the atom or molecule being defined, we have, as real propositions, the following: 'Matter is composed of atoms;' 'the atoms of matter attract each other.' This last proposition being one of wide generality, there fall under it many special propositions, or modes of attraction, for different kinds of matter; but, in this department, we are perpetually disposed to palm off verbal propositions for real—as in affirming that hard bodies have a powerful atomic cohesion. Examples of strictly real propositions are these:—crystals are hard bodies, that is, the cohesion of crystallization is intense in degree; crystals are usually brittle, or the cohesion of crystals is of a short range. Again, with regard to *Adhesion*, there is an important inductive generalization, that bodies of a *nearly similar* nature are those possessing mutual adhesion; thus metals adhere in solders and in alloys, earthy bodies, in cements and in cohesive mixtures, and so on. Farther, the *Diffusive* volume of a gas is inversely as the square root of its density.

These are propositions of co-inhering attributes, verified only by wide and exhaustive agreement through the whole sphere of the things concerned.

Another large class of propositions under the same department includes the numerical expressions of the degrees of the different attributes. These are the *constants* of the department, and need no farther remark.

The propositions of *Heat* have the reality arising in the concomitance of subject and object facts. Apart from this, they may be classified under the following heads. The first class takes in the deductions from the law of Conservation, confirmed by observation and induction.—such are the facts of the *dilatation* of bodies by heat, of which fusion and evaporation are special manifestations. There is herein comprised a wide field of natural phenomena; and many specific statements are needed to cover the variety of modes in different substances. Another class of propositions affirm, in their

several modes, the great molecular property named *Conduction*, a property with numerical degrees; while important laws of dependence or concomitance connect this property with the molecular properties of bodies. *Radiation* next demands to be considered, a fact with geometrical aspects and corresponding predicates; this part of the subject having a considerable parallelism to the leading facts of Optics. The specific rates of radiation of different bodies may be numerically ascertained, and laws enounced, whose character is jointly deductive and inductive. *Absorption* is another predicate, and similar remarks apply to it.

The exhaustion of the consequences of the Law of Conservation, would require a statement of the mode of deriving heat from Mechanical force (crushing, collision, or friction), and from the other molecular forces; and also the situations or arrangements whereby it returns to these again; the case of producing mechanical force having been given under the great fact of Dilatation.

On the whole, propositions of heat are (1) Derivatives from Conservation; (2) Constants, or numerical measures of the various phenomena for different bodies; (3) Laws connecting manifestations of heat with molecular structure; (4) Laws of situation, or conditions of the transmutation of Heat, to and from, the other energies, with the constants, expressing the rates of equivalence.

The foregoing account may suffice to exemplify the propositions of molecular physics. Were we to proceed to LIGHT, we should find a statement of definite phenomena—called radiation, refraction, reflexion, dispersion, colour—all expressed under numerical and geometrical relations. We should also find some cases of concomitance of attributes, as Double Refraction and Polarization. The connections of Light with Heat and with Chemical Force, being underivable from the great Law of Conservation, must be given as empirical inductions of co-inhering attributes, some of them of considerable generality, as the connexion of light with temperature; others narrow and special, as in the chemical relations.

ELECTRICITY has the advantage of being fully correlated with the other forces. It involves, however, great complexity of arrangements, as conditions of its manifestation in the various species; whence the propositions are greatly occupied in stating these arrangements or collocations; many of them being hidden in the molecular depths of bodies, and rendered in hypothetical language.

Predominant Methods of Physics.

10. Physics has been seen to be partly Deductive, and partly Inductive. The Inductions principally relate to Cause and Effect; while, in Molecular Physics, there are inductions of Co-inhering Attributes. The principles of Definition are appealed to, and more especially for the primary notions; but there is scarcely any opening for Classification.

As a Deductive Science, Molar Physics is a branch of applied Mathematics, checked and controlled by the perpetual reference to facts.

As an Inductive Science, Physics makes an unsurpassed display of the machinery and resources of Observation and Experiment. It also shows to advantage all the Methods of Experimental Elimination. The facts being subject to the great law of Conservation, the deeper experimental problems consist in ascertaining the collocations or arrangements for transmuting or evolving the different modes of force. The researches and discoveries relating to Heat, Electricity, and Light have this character to a very large degree.

The Hypotheses of Physics exemplify all the forms of Hypothesis formerly laid down. The chief instances—the Dynamical Theory of Heat, the Undulatory Theory of Light—have already been adduced in expounding the general subject. Another hypothesis of inferior weight and character is the two Electrical Fluids, for representing the polar phenomena of Electricity.

CHAPTER III.

LOGIC OF CHEMISTRY.

1. The relationships of Chemistry to all the departments of Molecular Physics are intimate and sustained. The special fact of the science is given in the name Chemical Attraction.

Chemistry deals with the union and the separation of elements; it regards all the substances of nature as either simples

or compounds ; the manner of union or composition being special to the science. There are unions not chemical ; as when bodies are pulverized and mixed together without farther intimacy. There is a still more intimate union in solution, which, however, also comes short of chemical union.

2. Chemical Attraction, or Union, involves these facts : (1) The Properties are definite. (2) In the act of union, there is Heat evolved. (3) The chief properties of the elements disappear.

A fourth mark, which may either enter into the definition, or be reserved as a predicate, is that chemical union takes place between *dissimilar* substances, while solution or adhesion is between *similars.* If reserved as a predicate, this property will be one of the properties forming real propositions, as exemplified in next section.

It is not necessary here to exemplify these defining properties. In a work on chemistry, it would be advisable to offer in advance a few illustrative cases, as a preparation for entering on the systematic detail.

This disposes of the leading *notion* of Chemistry, being the essence or connotation of the name, the Definition of the Science. A mistake in Logic is made when these properties are stated as *real* propositions ; they are not predicated of a *subject* called Chemical Attraction, they constitute or make up that subject.

3. The Propositions, or real predications, of Chemistry relate (1) to the circumstances, or conditions of Chemical change, (2) to the substances that undergo the change.

(1) When we have defined the fact of Chemical union, (with its correlative and implicated facts, Decomposition, Simple Body, Compound Body), we have to state the various circumstances, conditions, or modifying influences of Chemical change. This constitutes numerous real predications, of great theoretical and practical moment.

(2) The enumeration of substances that combine together chemically, or that bring about chemical decompositions yields a large mass of real propositions, under the general predicate of Co-existence, or Co-inhering attributes. Oxygen combines with hydrogen, and forms water ; sulphuric acid decomposes chalk, common salt, &c.

The expressions for the definite combining numbers are real propositions, corresponding to the 'constants' of Physics.

The relation of Chemical Force to the other Correlated Forces may be re-iterated at the commencement of the subject; although, as with the other preliminary statements, the understanding of it will grow with the unfolding of the future details.

Arrangement and Methods of Chemistry.

4. The division of Chemistry is into INORGANIC and ORGANIC.

Inorganic Chemistry is laid out under the succession of the Simple Bodies.

The distinction of Inorganic and Organic would exemplify definition with a broad doubtful margin. The basis of the distinction is the circumstance that a large class of highly important substances can be obtained only from living bodies; such are starch, sugar, albumen. This peculiarity of origin is associated with two other peculiarities, namely, the limited number of elements in organic bodies, and the great complexity of the chemical constitution. There would be a convenience in adopting all the three facts as a complex definition of Organic bodies, from which, by antithesis or negation, we have the definition of the Inorganic.

The Chemistry of the Inorganic or Mineral world comes first; and its method of arrangement is to adopt some succession of the Simple Bodies, and under them, to distribute the various Compounds.

Classification of the Simple Bodies or Elements.

5. The Simple Bodies, or Elements, are divided, in the first instance, into Metals and Non-Metals. Although there are transition elements, as Tellurium and Arsenic, the distinction is founded on important differences.

The Metals have certain prevailing characteristics, but yet in a varying degree, and with occasional exceptions. (1) Most striking are the *visible* properties—Opacity, Lustre, and Colour. Metals are opaque; they have the peculiar lustre termed metallic; and their colour is white or grey, with the exceptions—Gold, Copper, and Titanium? which are yellow. (2) They are *solid*, Mercury and Hydrogen being notable exceptions. The solidity is usually joined with compactness of structure, as shown in the properties—hardness and tenacity. (3) They are comparatively good conductors of *Heat*. (4) They are conductors of *Electricity*. (5) They are *Electro-positive*. (6) They com-

bine chemically with the Non-Metals. (7) Their compounds with Oxygen are for the most part *Bases*, and not Acids.

The question is not here raised how far some of these properties are implicated in others. Since the implication is not obvious, the properties are provisionally given as distinct. A more important remark, from the logical point of view, is the occurrence of exceptions to almost all the properties. In the complex defining of natural objects, we must be prepared for this circumstance, which does not render the classification vain or nugatory. Although mercury is a liquid we neither surrender the property of solidity, nor exclude it from the class. Solidity is wanting only in two; and mercury has all the other six properties. This is probably one of the cases where Whewell would desiderate a *type*, or average representative specimen, some metal possessing in fair measure all the prevailing characters.

The Non-Metals are defined by the antithesis of the above group of properties. As regards Light they are not uniformly opaque, and when opaque, they are, except selenium, wanting in lustre. There is only one Gaseous metal, there are four gaseous non-metals. They are non-conductors of Electricity, and Electro-negative. Their compounds with oxygen (one of their number) tend to Acids, and not to Bases.

Whenever a classification is possible, there must be common properties, and these are possible to be stated. Still, in the usage of Chemical writers, the statement of the generic properties of the classes 'metal' and 'non-metal,' does not dispense with the repetition of these in the detail of the species. The Natural History methods, not being susceptible of extensive application in Chemistry, are hardly attended to, even where admissible. Nevertheless, as the situations arising in the classification of the Simple Bodies are highly illustrative of situations in Botany and in Zoology, we may follow out the present case a little farther.

6. Both Metals and Non-Metals are sub-divisible into smaller classes or groups.

In the Metals, there are certain groups that have important affinities—such are the Alkali-Metals (Sodium, &c.), the Alkaline-Earth Metals (Barium, &c.), the Earth-Metals (Aluminium, &c.), the Noble Metals (Mercury, Silver, Gold, &c.) remarkable for refusing combination. A group is also indicated by the important fact—exceptional to the tendency of the metals as a whole—namely, forming acids with oxygen. A few,

presenting analogies to iron, make an Iron group—Manganese, Cobalt, Nickel, Chromium, Uranium. A certain amount of resemblance suggests the juxta-position of Zinc, Cadmium and Magnesium. (Miller's Chemistry, I. 11).

The expository succession adopts the order of greatest resemblances. The succession is necessarily linear, and leads inevitably to the wide removal of bodies that agree in some important particulars. The idea is sometimes conceived of a circular, or superficial arrangement for bringing together resembling bodies on two sides; while, by a diagram of solid dimensions, each body may be brought into relationship on three sides. Still, the expository order can follow but one course, indicated by the maximum of resemblance; and provision has to be made under each body for indicating agreements between it and bodies in other groups.

There can scarcely be any doubt as to the propriety of placing the substances of strongest chemical affinity at one end of the line (Hydrogen, Potassium, &c.), and of weakest affinity at the other end (the noble metals).

The Non-Metals (13 in number) contain a few groups, and some isolated individuals. The *halogen* group of Berzelius—Chlorine, Bromine, Iodine, and Fluorine; and the *sulphur* group—Sulphur, Phosphorus, Selenium, and Tellurium—are classed as having considerable and important resemblances. Silicon and Boron have points in common: and their suffix *on* was given to show some small analogy between them and carbon. The substance of most marked isolation is Nitrogen; while Oxygen is pre-eminent by the catholicity of its chemical affinities.

By unanimous consent, Oxygen has precedence. The second place is variously assigned. To take up Hydrogen could never have been strongly justified, and is now less so than ever. For the single advantage of having Water brought forward at an early stage, a leap is taken to the extreme opposition, making the last first. Most is to be said in favour of Nitrogen, as the second body. Remarkable for its chemical neutrality, it also gives an opportunity for dwelling on the mechanical peculiarities of gaseous elements; and it may be followed up by the consideration of the Atmosphere—a mechanical admixture of Oxygen and Nitrogen.

Except to hurry on to familiar and interesting combinations there is no need to bring forward carbon among the very first; the nearest kindred to oxygen is found in the halogens—Chlorine, &c. To these might follow Carbon, and perhaps

Boron and Silicon, while the Sulphur group would close the array. Leaving the question open, whether Carbon, Silicon, and Boron, should one or all precede or follow the Sulphur group, the rule of arranging by the maximum of agreement on the whole would be best carried out thus:—

Oxygen,	Chlorine,	Carbon,	Sulphur,
Nitrogen,	Bromine,	Boron,	Phosphurus,
	Iodine,	Silicon,	Selenium,
	Fluorine,		Tellurium.

Since the exposition of Chemistry follows a certain order of the Simple Bodies—the Non-Metals first, and the Metals next—some consideration is necessary in order to assign a place for the Compounds, which far outnumber the Elements. As it would be inconsistent with the very nature of the subject to separate the Compounds from the Simples, seeing that the chemical characters of a simple body are expressed by its forming compounds with other bodies, the Compounds must be interpolated in the exposition, and appended to such of the Simple Bodies as they are most intimately allied with.

Hence there will always be a choice of positions; the compound 'water' may be attached either to the element oxygen, or to the element hydrogen.

There is one obvious consideration applicable to this peculiar emergency. A compound need not be brought forward for full description till all its elements have been stated; water may wait till hydrogen is given; carbonic acid may follow carbon, oxygen being previously given; the salts may be appended to the metals that are their bases. Yet this arrangement is not without its disadvantage. The element given last may not be considered the most important in regard to the characters; thus hydrogen is the completing element of so many important compounds, as, for example, the hydrogen acids, that, supposing it placed at the head of the metals, it would be followed by an enormous crowd of compound substances; many of which would seem more naturally related to other elements, as the acids to their several radicles—nitrogen, chlorine, sulphur, &c.

The difficulty in this particular instance may be supposed to be got over, by the expedient of bringing on hydrogen soon after oxygen. The operation, however, begins by an act of violent transposition that may be expected to land us in some other fix. And so it is. Enabling us without loss of principle to attach the acids to their several radicles—nitric acid to nitrogen, &c., the proposed step compels an abrupt stoppage

where there is a natural transition, namely from the acids to the salts. In point of fact, the barrier is always forced at this point; the salts are brought in, notwithstanding that the metallic bases are still far ahead. Thus, after all, the transplanting of hydrogen from its proper allies merely postpones an inconsistency for one moment.

On the other hand, it may be maintained that the proper place of the important hydrogen compounds is after hydrogen; its most characteristic feature being to constitute and complete these compounds. The class 'hydrogen acid' is connoted by the presence of hydrogen; sulphuretted hydrogen and sulphuric acid are more in place among hydrogen acids than among sulphur compounds. This alone would be a strong reason for not bringing on hydrogen till the end of the non-metals, in which are contained the other acid constituents. If these acids are disposed of first, the interest of hydrogen is used up; except as composing water, everything about it is become stale.

Descriptive Characters of Chemical Substances.

7. The description of bodies in Chemistry, whether the Simple Bodies or Compounds, should coincide with the expository order of the properties—physical and chemical.

In Chemistry, no less than in the Natural History sciences, a regular and uniform plan, in the descriptive arrangement, is more than an aid to memory; it is farther an instrument of investigation. The plan adopted in Chemistry, slightly modified, will serve also in Mineralogy.

The Chemist professedly exhausts the physical as well as the chemical characters of each substance. Hence the scheme should comprise both groups in the best order of succession; which order, as regards physical properties, is seen in the exposition of Molecular Physics. There are some open points of arrangement, chiefly with reference to the Crystalline form and the Optical properties. Apart from these, the succession would be Molecular Cohesion, Heat, Electricity. If the CRYSTALLINE form is viewed in the first instance as a purely geometrical fact, it might take precedence of all Physical properties. The OPTICAL properties, stated as such, without enquiring into their connexions with molecular structure or with chemical arrangements, might be given next. The priority of these two properties would have the expository advantage of mentioning first what soonest strikes the senses;

the eye taking the lead in the scrutiny of whatever is visible.

To the Crystalline and Optical properties might succeed the Specific Gravity.

Next in order would be the properties hypothetically resumed as modes of Cohesion :—Hardness, Tenacity, Elasticity.

There would then succeed the properties summed up in Adhesion :—Solution, Diffusion, Osmose, Effusion and Transpiration (of gases).

The relations to Heat, are given in the following properties :—Rate of Dilatation ; Melting and Boiling Temperatures ; Conduction ; Specific Heat, Latent Heat, Radiation, Absorption, Refraction, Polarization.

Relations to Electricity :—Magnetic Property ; Conduction or Insulation of Friction Electricity ; Conduction or Insulation of Voltaic Electricity ; place in the Electro-positive to Electro-negative series ; place in the Thermo-electric series.

The Chemical properties are—Chemical Composition (if not an Element); the bodies that the substance combine with ; the circumstances of the combinations ; and the agency of each in decompositions.

Of these characters, two—Adhesion and Chemical Attraction—are by their nature *correlative* characters ; they involve the mutual action of at least two substances. With reference to them, the property of any one body is relative to some second body ; a substance is not universally adhesive, nor universally disposed to chemical unions. Hence the account of the Adhesive and the Chemical properties is complicated and not easy to manage. There is from this cause, an especial difficulty in giving an adequate notion of the bodies that happen to come first ; indeed it is impossible to do justice to Oxygen, for example, until a great many more bodies are described, namely, the long list that oxygen combines with.

The proper course, in such circumstances, is to avow the difficulty, and not to expect that a learner can receive other than an inadequate or half notion of Oxygen, until he has come on to the full description of such bodies, as Carbon, Sulphur, Hydrogen, and a few of the metals.

Examples of Description.

(1) *Light.*—A gas. Transparent and colourless. Index of Refraction 1.00027.

(2) *Specific Gravity* 1.1056 ; the atmosphere being 1.

(3) *Adhesion for other substances.*—Solubility in water, from

about one twentieth to one thirtieth of its bulk (.04114 at 32° F.; .02989 at 59° F.).

(4) Relations to *Heat*.—Rate of Dilatation not stated. As regards the temperatures of Liquefaction and Freezing, has never been liquified, although condensed to $\frac{1}{554}$ of its bulk. Specific Heat, about one fourth of water (.2405).

(5) Relations to *Electricity*.—Is a magnet at common temperatures. In the Voltaic series, it is at the head of electro-negative elements.

(6) *Chemical* relations.—Speaking generally, it is the most widely-combining element in nature. With a doubtful exception (fluorine), it combines with every known element; not merely its natural opposites, the metals, but non-metals likewise. Classes of leading importance in chemistry are compounds of oxygen with the other elements; the oxides of the metals are what are termed *bases;* the oxides of the non-metallic elements are generally *acids*. With Hydrogen, it yields *water*. The act of combining with Carbon, either alone, or along with hydrogen, is the most familiar example of violent and rapid chemical union, with evolution of heat and of light, and is termed 'combustion.'

The peculiar circumstances attending the combinations of oxygen vary with the character of the second element. Thus, in the leading fact—*Heat of combination*—the maximum evolved is with Hydrogen; Carbon yields one fourth of that amount; Phosphorus, about a sixth; Sulphur, about a fifteenth; Zinc, Iron, Tin, about a twenty-sixth.

Atomic number, 16.

As regards the conditions of entering into combination, there is great variety, from the extreme of readiness at the ordinary temperature of the atmosphere, to the extreme of indifference, conquered only by the aids to combination, namely, artificial condensation, heat, the electric spark, the contiguity of chemical action already begun, &c. Part of the peculiarity is due to the state of oxygen itself:—which may be either in the ordinary atmospheric dilution; or prepared apart free from any other gas (whereby all combinations are acclerated); or, lastly, in combination with other bodies as in water (a powerful oxidizer); in the nitrates, in chlorate of potash—which salts permit of the liberation of their contained oxygen in a highly *concentrated* form.

Local spread of Oxygen.—Need not be here detailed.

Modes of obtaining Oxygen.

I doubt the propriety of including, under Oxygen, any more

detailed account of the oxygen compounds. There are better opportunities afterwards, under the several elements that form the other members of the compounds,—carbon, hydrogen, the metals, &c. Nor is it necessary to bring forward Combustion, of which a sensational use is commonly made, in the description of oxygen. A disproportionate prominence is thereby given to what is, strictly speaking, incidental only to some of the modes of oxidation, and is found in other chemical combinations if they happen to be rapid and energetic. Combustion is a special thesis under the general head—Chemical Union, its conditions, and circumstances—and is of great importance both theoretically and practically, but it need not be appended to Oxygen. If involving too much anticipation of details to be given in the preparatory view of Chemical Combination (where, however, it might be briefly indicated), it might be brought in at some convenient point, by way of digression, as for example, at the end of Carbon, the chief element in ordinary combustion.

OZONE.—A supposed allotropic form of Oxygen, under which the oxygen is rendered more active in entering into its various combinations.

The *specific gravity* of ozone is greater than of oxygen.

Adhesion.—It is not soluble in water, nor in acids or in alkalies; but it is soluble in iodide of potassium.

Relations to *Heat.*—Its active character is destroyed by a temperature not much above boiling water.

Relations to *Electricity.*—The transmission of a series of electric sparks through dry oxygen is one of the modes of producing it.

Odour.—It has a characteristic odour, whence its name.*

Chemical properties.—While it does not combine with any substance but those that oxygen combines with, it combines at temperatures, and under circumstances where oxygen does not combine. Hence it is a powerful oxidizing agent—in oxidizing metals, in destroying vegetable and animal compounds, in bleaching, in purifying the air from miasmata, in stimulating the respiratory organs.

Modes of preparing Ozone.

Remarks on Ozone.†—It is interesting to note the power of electricity to give a new combining aptitude to oxygen.

* *Taste* and *Odour* may provisionally be given after Electricity, and before Chemical properties. They are doubtless a consequence of Chemical re-actions.

† The heading 'Remarks' is intended, among other uses, to avoid the

NITROGEN.—A gas.

As regards *Light*, transparent, colourless; Refracting Index, 1.0093.

Specific gravity.—.9713. Atmosphere 1.

Adhesion.—Water dissolves about a thirtieth of its bulk at ordinary temperatures.

Relations to *Heat*.—Dilatation not stated. Never been liquefied. Specific Heat, slightly less than Oxygen, .2368.

Relations to *Electricity*.—Next to oxygen in the Electro-negative series.

Chemical relations.—Nitrogen enters into a very limited number of compounds. Where it does combine, it is singularly inert, or indisposed to enter into combination; demanding to be placed in the most stimulating conditions. Many interesting consequences in vegetable and in animal life are traceable to this peculiarity.

Compounds with *Oxygen*.—Recited in so far as illustrating Nitrogen.

Compounds with *Hydrogen*.—Ammonia, &c.

Compounds with *Carbon*.—Cyanides.

Spread of Nitrogen.—Modes of obtaining it. Remarks:—bearings upon Chemical theory.

The next example is a solid element.

CARBON.—A solid, in two states—crystallized *Diamond*, and amorphous *Graphite*. These occur in such a degree of purity that they may be taken as typical of the element.

(*Diamond*).—The Crystallization, Optical Properties, Specific Gravity, need not be here recited.

Cohesion.—The hardest body known; hence at the top of the scale of mineral hardness.

Adhesion.—A very important circumstance as regards other forms of carbon, but not ascertainable in the diamond itself.

Relations to *Heat*.—Is not fused or volatilized by the highest known heat; is not known to exist either as liquid or as vapour. An intense heat merely reduces it to a black opaque mass.

Relations to *Electricity*.—A non-conductor. Carbon has a high relative place in the Electro-negative series (place given).

Before stating the chemical relations, a similar recital should be given for the other form, *Graphite*.

Chemical relations. The range of elements combining with carbon comprises—Oxygen, Nitrogen, Hydrogen, Phosphorus, Sulphur, and many Metals, especially Iron. It does not enter

confusion and perplexity of introducing speculative considerations into the methodical description.

into combination unless at high temperatures, and then combines with rapidity and copious evolution of heat.

Compounds with *Oxygen.*—Carbonic Acid, Carbonic Oxide (described at full length).

With *Nitrogen.*—Cyanogen; alluded to.

The other compounds may be postponed.

Spread and *Sources* of Carbon.—Impure Forms.

Remarks on Carbon.—Combustion.

These examples are sufficient for the purpose of indicating a systematic mode of describing the elementary bodies. They would apply equally to compounds. In them, however, the chemical relations involve another circumstance, namely, the modes of decomposition.

In certain of the elements, the chief practical interest is found in impure forms—alloys, or mixtures with other ingredients; for example, Iron. Still, it is desirable, for theoretical completeness and consistency, to advert, in the first instance, to a pure or typical form, in order to know what the substance is in itself, both physically and chemically. The alloys or mixtures may then be given; but before their practical bearings are touched upon, their properties are to be recited as illustrating the changes brought about by mixture, thereby contributing facts to the inductive laws of Adhesion.

8. In Descriptive Method, it is of importance not to mix explanations and theorizings with the description.

In describing a quality, the first thing is to state precisely what it consists in, or how it is discriminated. Moreover, the whole series of qualities should be gone through, in the first instance, and no attempt made to connect them with one another, or with other properties, in general laws. This last operation should always be kept distinct. The remark applies to every science where description enters.

9. When bodies are closely allied in their nature, and are in consequence grouped as genera, their differences should be exhibited in marked contrast.

The Halogens among the non-metals, the Metals of the Alkalies, &c., make groups or genera, with agreeing peculiarities. These points of agreement are stated at the outset, so as to abbreviate the details of the species. Attention should next be given to contrasting pointedly the agreeing members among themselves. Thus Sodium and Potassium agree to a

very large extent; and after the agreements, the differences should be given in a tabular antithesis.

10. The generalities of Chemistry are *Empirical Laws.*

The Atomic Theory is commonly said to be the highest generalization of Chemistry. This, however, must be guardedly stated so as not to confound definition with propositions. The nature of Chemical Attraction is expressed in a complex definition (Definite numbers, Production of Heat, Merging of elements). There may be real predication in declaring these three facts to be conjoined; and their conjunction may be resolved into higher laws, or converted from an empirical to a derivative conjunction.

The propositions, in connexion with Chemical action, that have in the highest degree the character of *real* concomitance, are those that affirm the conditions, arrangements, or situations attendant on combination and on decomposition.

For example, Combination requires proximity of the elements, and is favoured by all the circumstances that aid proximity, as liquefaction; it is resisted by strong cohesive or adhesive forces, and proceeds as these are released. It is brought on by elevation of temperature in numerous instances. It is induced by the electric spark; which may operate by mere rise of temperature, but more probably by polarizing the atoms. It is promoted by concurring combinations; it accompanies decompositions. These are all empirical laws. They are, moreover, statements as to general tendency, and need to be accompanied, each with a schedule, stating the individual substances and situations of their applicability.

Many other laws might be cited:—The celebrated law of Berthollet, regarding the double decomposition of salts; the laws that simple substances exhibit the strongest affinities,—that compounds are more fusible than their elements,—that combination tends to a lower state of matter—from gas down to solid.

As Empirical laws, these have no other verification but Agreement; they are only surmised to be laws of causation; they are limited to adjacent cases.

11. The ultimate generalizations of Chemistry must fall under the Law of Conservation of Force, and must express the most generalized conditions of the re-distribution of Chemical Force.

The Law of Persistence over-rides every phenomenon of

change, but it must be accompanied in each case with laws of Collocation. In Chemistry, there must be indicated the precise conditions of chemical re-distribution, whether in combination or in decomposition. It is necessary to find out, in the most general form, the situation or situations that bring about chemical change, in either direction. If this can be comprehended in one law, that will be the highest, the ultimate law of Chemistry, the Chemical appendage of the Law of Conservation. The Empirical laws above quoted will then have the improved character attaching to Derivative laws.

12. Chemistry contains, as a part of its nature, numerous *Hypotheses*. These are mainly of the class named Representative Fictions.

To express in the most general terms the numerous phenomena of combination and decomposition, certain arrangements of the component elements of the compounds are assumed hypothetically. It is a *fact* that sulphate of potash contains certain proportions, by weight, of sulphur, oxygen, and potassium; it is a *hypothesis* that the salt is made up in the particular way shown by the formula KO,SO_3, being a binary compound of two other compounds.

The Atomic Theory of Dalton contained a generalization of facts embedded in Hypothesis. The facts were the fixed proportions of bodies combining chemically; the hypothesis, that each substance is composed of atoms, and that, in chemical union, an atom of one substance joins with one, or with two, or with more atoms of another; there being always a neat numerical relation without remainder. No one now regards this as more than a representative fiction, unsusceptible of any other proof than its facility in expressing the facts.

The Constitution of Salts is the great battle ground of chemical hypotheses, being the key to the entire structure of chemical representation. There is, however, a perfect understanding as to the nature of the proof to be offered for the rival hypotheses, namely, the suitability to comprehend the greatest number of chemical re-actions, or combinations and decompositions. It is a question purely chemical, and not in anywise logical in the sense of demanding attention to be recalled to neglected logical principles.

As examples of the subordinate hypothetical points, we may quote the singular idea of supposing an element to combine with itself—hydrogen with hydrogen, chlorine with chlorine, and so on; a very great stretch, seeing that opposition of ele-

ments is a predicate of chemical union. A better example of a likely hypothesis is the proposal to assign to bodies of different properties, having the same ultimate constitution, a different proximate constitution; as formic ether and acetate of methyl. The bold hypothesis of Gerhardt and Griffin—to regard as two substances, iron when entering into proto-salts, and when entering into sesqui-salts, and the same with all other elements producing sesquioxides—was considered as a relief from otherwise inextricable difficulties.

The hypothesis of the Atom, or lowest chemical constituent is now coupled with another hypothetical entity—the *molecule* representing the smallest number of atoms of each substance supposed to possess separate action. Thus the molecule of nitrogen is said to be made up of 2 atoms; the phosphorus and arsenicum molecules, 4 atoms, and so on.

When a number of different salts are in the same solution, as in a mineral water, it is a matter of hypothesis which acid is attached to which base. (Miller's Chemistry, II. 824.)

The class of Scientific Hypothesis consisting of *unverified theories,* does not require special mention in Chemistry. Apart from the representative fictions, essential and permanent in the science, there are no hypothetic forces or agents. The great prevailing agent or cause of chemical change is, and can only be, a molecular aspect of the great primeval force named under the Law of Conservation. Until the supplement of this law, as regards chemical transformation—the universal conditions or collocations—be worked out, there will be many hypothetical *collocations,* which will be susceptible of final proof or disproof.

Nomenclature and Classification of Chemistry.

13. The Nomenclature and the Classification of Chemistry involve these points:—(1) The use of a symbol for each elementary substance; (2) The expression of the ultimate constitution of compounds; (3) an expression of the supposed proximate constitution of each compound in a manner suited to its re-actions with other bodies.

(1) The symbolical notation has the advantage of affording a brief and yet full expression to the most complicated compounds, rivalling, in this respect, the notation of Mathematics. It also enables bodies of like composition to be readily classed, and their class indicated to the eye.

The nomenclature for expressing in terms the various bodies

is made up of the names of the elements—Oxygen, Carbon, Iron, Silver—and of a systematic mode of uniting these in compounds—carbonic acid, carburet of iron, &c. Only binary compounds are stateable in this way; a higher combination is expressed in some supposed binary resolution—sulphuric acid, acetate of potash, chloride of formyl. Substances like sugar, starch. albumen, are given in their familiar names. Hence double naming is, in Chemistry, a special and limited process; and has no analogy to the names of species in Botany and Zoology.

(2) The notation exhibits the ultimate constitution of all compound bodies, by stating their constituents and the proportions of each; H_2 O is the analysis of water; F O, protoxide of iron; F_2 O_3, peroxide or sesquioxide.

(3) The symbols are farther accommodated to give the hypothetical upbuilding of the elements in complicated compounds; as in the theory of Salts. The ultimate analysis gives the amount of oxygen in a compound, and the formula states in what ways the oxygen is supposed to be distributed; an oxygen salt, in the old theory was a binary compound of two oxidized radicles, the oxide of a non-metal (as sulphur) and of a metal (as iron); sulphate of iron (protoxide) S O_3 Fe O. The analytical (or Empirical) formula of acetic acid is C_4 H_4 O_4; of the rational or hypothetical formula, there are no less than seven renderings (Miller's Chemistry, vol. III, p. 6).

14. A desideratum in Chemical Nomenclature is the statement of the structural Heat of the bodies.

The formula H_2 O is given indifferently for steam, water, and ice; although the exact difference of structural heat in the three admits of numerical statement. Calling *ice* H_2 O; we may call *water* H_2 O $+$ 180°; *steam* H_2 O $+$ 1180°, on the usual reckoning of the heat of boiling and of evaporation.

Farther, when Hydrogen and Oxygen combine, there is a great evolution of structural heat, which is lost to the compound; a provision might be made for indicating the exact figure, which has been found out by experiment; a certain minute quantity would be attached to H_2 O, on this account, and about one fourth of that quantity to C O_2.

CHAPTER IV.

LOGIC OF BIOLOGY.

1. Biology is the Science of Living Bodies—Plants and Animals; its exact definition is the definition of Life.

Definition of Life.

2. Life is to be defined by a generalization of what is common to Living Bodies.

The Denotation of the term Living Body is well fixed; there is scarcely even a debateable margin between the Organic and the Inorganic worlds.

Choosing Assimilation as a characteristic fact of bodily life, and Reasoning, as an example of mental life, and contrasting both with the characters of dead matter, Mr. Herbert Spencer arrives at the following highly complex definition:—

1. Life contains a process or processes of *change*.
2. The change is not a simple or individual act, but a *series or succession of changes*.
3. Life involves a plurality of *simultaneous*, as well as successive changes.
4. The changes are *heterogeneous*, or various in character.
5. The various changes all *combine* to a *definite* result.
6. Finally, the changes are in correspondence with *external co-existences and sequences*.

In sum:—Life is a set of changes, simultaneous and successive, combined to a definite result, and in correspondence with external circumstances. Or, in a briefer form, Life is the continuous adjustment of internal relations to external relations.

So carefully has the comparison been conducted, that no exception could be taken to any part of this definition. Every one of the particulars occurs in all living bodies, and in no kind of dead matter. The apparent defect of the definition is omission; it does not express or seem to suggest points that strike the ordinary observer. For example, there is no allusion to the organized structure, at the foundation of which is the peculiar constituent known as the cell, or nucleated corpuscle. Again, there is no mention of the individual and independent

existence of living bodies; with which is also associated the cycle of birth, growth, and death.

These omissions, real or apparent, might be defended or explained on one of three different grounds.

First, it might be said, that the facts mentioned, although present and conspicuous in many or in most living bodies, are not found in all, and therefore cannot be adopted into the general definition. They can be taken notice of only in defining the classes or subdivisions of the whole kingdom of animated nature. This remark would be a sufficient justification, if it were true; but it is not true, at least to the extent of excluding the mention of the circumstances from the definition.

Secondly, it might be said, that the definition does not aim at being exhaustive, but only at being discriminative; while it is based on essential characters, it does not profess to give *all* the essential characters. Enough is given to prevent us from ever confounding a plant or an animal with a stone; but there is no intention of stating every feature that separates living bodies from the inanimate world.

To this the obvious reply would be, why should all the essential characters not be given? There is no apparent reason for omitting in the statement whatever can be discovered as common to the whole department of animated nature.

Thirdly, it might be alleged, that the aspects in question although not appearing on the surface of the definition, are yet implicated on it, and are unfolded in the due course of the exposition. The definition, it may be said, goes to the root of the matter; while all else branches out from that, and is duly unfolded in the subsequent exposition of the science.

In order, however, to bring forward at once whatever can be assigned as general characters of living bodies, whether primary or derived, we shall re-cast the definition, and distribute it under the heads—Constituent Elements, Structure, and Functions.

3. I. Living bodies are constituted from elements common to them with the inorganic world.

The chief constituents of Living bodies are these four—Carbon, Hydrogen, Oxygen, Nitrogen; the last, Nitrogen, being most abundant in animals. To these are added, in smaller proportions, Phosphorous, Calcium, Sulphur, Chlorine, Fluorine, Sodium, Potassium, Iron, Magnesium, Silicon.

The various properties, Physical and Chemical, belonging to the several elements are found operative in their organized form. All the mechanical and molecular laws are traceable in living bodies.

Chemically considered, organic bodies, are exceedingly *complex* compounds. The department of Organic Chemistry is devoted expressly to these compounds. According to the chemical reckoning, a single atom of an organic substance, as sugar, starch, albumen, contains hundreds of simple chemical atoms; the atom of albumen is said to be made up of 880 atoms of the four chief organic elements.

II. With reference to STRUCTURE.

(1) Living bodies possess a peculiar structural complexity, commonly called the *Organized Structure*. Associated with our notions of life is a certain mechanism, or machinery, very various in its extent and complication in individuals; attaining in the higher animals a degree of complicated adjustment unequalled in any other department of nature. Such structures as the eye, the ear, the brain, of human beings are, in our conceptions, the very acme of structural mechanism.

It is now known that the ultimate constituent of all the variety of structures is a microscope element called a *cell*, or nucleated corpuscle; by whose aggregations and transformations, tissues are formed, which tissues make up the organs. It is true that in certain low forms, both plants and animals, the cellular structure is not apparent, and therefore its visible peculiarities — namely, the bounding pellicle and internal nucleus—are not absolutely essential; still, we cannot omit from the definition an arrangement so completely bound up with all living nature, the few apparent exceptions being equivocal.

(2) Another prominent feature of the living structure is *Individuality*, or individuation. Living matter instead of existing in vast continuous masses, like rock, is separated into distinct individuals. As with other peculiarities, however, there is an ambiguous margin here also. In animal life generally, and in plant life generally, we have no misgiving as to individual existence; men, sheep, forest oaks, are all distinct and separate. Still, a scientific definition must grapple with the whole field of cases, having merely the requisite latitude of a small doubtful margin. Mr. Spencer defines the individual, with reference to his definition of Life, as any concrete whole performing within itself, all the adjustments of internal

to external relations, so as to maintain its own existence. This definition, to a certain extent anticipates Function, but so does any adequate statement of Structure; the separation of Structure and Function is one of great logical convenience, but, in nature, the two things are inseparable.

With Individuality there is closely associated, in our conceptions of living beings, the Cycle of existence, the derivation of one living being from others, and the necessary termination of each individual's existence, after a definite career. Here, too, we may seem to anticipate what belongs to Function.

(3) We may not improperly state in connexion with structure, and as following on Individuality, a circumstance so notorious, that to omit it from the comprehensive statement of life would appear inexplicable, namely, the vast *Variety of Forms and Structures.* Uniformity, comparatively speaking, pervades dead matter; variety is the characteristic of living substances. The different forms of Plants and of Animals count by thousands; there are upwards of one hundred thousand species of Plants, and a still greater number of Animal Species; while of every one of these distinct species, there is an indefinite unceasing multiplication of individuals, nearly, although not absolutely alike.

One of the chief demands of Biological science is to find an orderly arrangement for such a host of various forms. This makes Biology, *inter alia*, a science of Classification.

III. As to FUNCTIONS.

The living structure is naturally active, changing, productive, and its most characteristic points must have reference to these activities. Here we may embrace the substance of Mr. Spencer's definition, in two principal heads—Change, and Adjustment to external circumstances.

(1) A definite combination of changes, simultaneous and successive.

(2) An adjustment to external circumstances.

(3) It must seem unpardonable, however, not to bring out into prominent statement at the outset, that very remarkable phenomenon of living bodies, to which there is no exception, namely, *Assimilation*, or the power of an existing organized particle, to impart its own organization to an adjoining particle having the proper chemical constitution. This magic touch of vitality, has only a faint parallel among inanimate bodies: combustion, and chemical combinations generally, make but a small approach to it. Its lesser manifestations are in the

renewal, by nutrition, of the living tissues; its culmination is in the throwing off of the germ, or seed, apparently homogeneous and structureless, but possessed of interior markings that decide whether its future is to be a man or an oak; a white man, or a negro; a flat nosed or an aqulline-nosed man or woman. We may not be able to consider whether this great property be essential and fundamental, or whether it be derived from other properties, already given in the definition.

We may repeat under this head, the peculiarity above adverted to, under individuality of structure—the Cycle of existence, or birth, growth, and death.

(4) It cannot be irrelevant to the comprehensive definition to advert to the connexion of *Mind* with Living Bodies. True, this is not a concomitant of *all* living bodies, yet it appears only in connexion with the living form. When we make the first great division of life, into Plants and Animals, we obtain the more precise boundary of the mental manifestations. Still, at the very outset, we are interested to know that this characteristic manifestation appears only in the department of living structures.

The foregoing definition professes to leave out no fact that can be found inhering in all living bodies. The first requisite in defining is to be exhaustive; it is an after operation, of great scientific interest, to trace the dependence of one or more properties upon the others, and to assign what appears to be the ultimate and underivable properties. At present, however, all such derivation is but tentative and hypothetical, and therefore, is not suitable to be brought forward at the commencement of the subject. Provisionally, these various peculiarities are to be held as distinct; no one being assignable as a derivative of another.

Divisions of Biology.

4. The Divisions of Biology are in conformity with the Definition.

The first part of the Definition refers to the Organic Chemistry of Life. This subject is partly given under Chemistry, and partly as the Introduction to Biology.

The two other parts of the definition suppose a separate consideration of Structure and of Function. We should fully understand the reasons and the limits of this separation.

These two facts are inseparable in the reality. But as, in less complicated subjects than Life, we have often to make abstraction of some qualities to the exclusion of others where there is no actual separation possible, so in the present case we find it advisable to consider Structure by itself, before viewing it as connected with Function.

Yet this separation may be carried to an unjustifiable extreme. As soon as the mind has perfectly comprehended a structural arrangement, we are prepared to enter upon the uses or functions of that arrangement. Indeed, while the knowledge of the structure is still fresh, the knowledge of function should be imparted. Function completes and fixes the idea of structure, in so far as the two are manifestly connected. The only reason for not following up the account of structure, with the account of function, for every distinct living organ, would be the necessity of viewing Function as a connected whole, and therefore not to be entered on unless it could be given as a whole. For example, the Function of Digestion could not be entered on till the entire group of alimentary organs were structurally described.

The separation of the two subjects is carried to a questionable extreme in the special Biology of man; Anatomy and Physiology being, by present convention, treated in distinct works, and taught by distinct teachers in the schools. The just middle plan would be to include both in one work, and to append to the Anatomy of each organ—Bones, Muscles, Heart, &c.—the Physiology or function.

In the usual treatment of Plant Biology, Structural Botany is given first, Physiological Botany next (in the same treatise); the student being made to wait for the account of Function in any organ until Structure has been gone through in every organ. The justifying reasons are probably these:—(1) It is possible to carry provisionally the whole structure in the mind, without the assistance that function would give; and (2) there is a convenience in treating function as an unbroken whole.

In Animal Biology, the branch called Comparative Anatomy takes each organ apart, giving both structure and function, and exhausting the varieties of each through the animal series.

Structure has to be viewed, in its successive modifications, through the cycle of the individual life. This is called Embryology. A still more extended view is the consideration of successive structures in the hereditary line, where there may occur changes requiring to be taken account of,

being the initial step of the new biological department called Evolution.

It is proper to generalize to the utmost the wide variety of structures, and to exhibit all the generalities apart as giving a mental command of the entire field. Such generalities would be called General Morphology, and General Embryology.

FUNCTION, or Physiology, is an account of all the living processes, in the most convenient order; all those changes constituting Life—changes simultaneous and successive, contributing to a definite result, and adapting each organism to the environment. Here there is an unlimited scope for inductions, and for deductions, confronting and correcting one another. The high generalities of Function comprehending *all* Life, if such there be, would form a General Physiology.

The subject of Evolution involves the mutual actions and modifications of Structure and Function. It deals with the general truth that when external circumstances demand and prompt an increase of function (as when an animal is called to exert unusual muscular energy) the structure is liable to be increased, and thus to increase the function apart from stimulation. This is one way of the supposed re-action of Structure and Function. Another way is by Mr. Darwin's Natural Selection, or Survival of the Fittest. The carrying out of these principles is the substance of the great Biological Hypothesis of Development or Evolution.

Biology can to a certain extent be treated as a whole, there being certain things common to living beings—Constituents, Structure, Function and Evolution; it would then have to be divided, as has always been usual, into Plant Life and Animal Life; each of these subjects being subdivided according to the plan above laid down for the whole.

Remaining Notions of Biology.

The general definition of Life has been seen to carry with it the definitions of *Organization, Cell, Protoplasm, Assimilation, Individual, Germ, Reproduction, Growth, Death.*

The specializing of the structures and functions introduces many other Notions.

Plant—Animal.—The greatest line of demarcation in living bodies is between Plants and Animals; these are the two highest genera of living bodies, a perfect dichotomy of the whole. Allowing for a doubtful margin, the distinctive characters are numerous and important. As in all dichotomies, we have the advantages of a definition by Antithesis.

The leading characters may be stated in contrast thus :—

PLANT.	ANIMAL.
Number and complexity of Tissues, Organs, and Functions.	
Small	Great
Local habitation.	
Fixed	Moveable (Locomotion)
Food materials.	
Inorganic	Organic
Mode of reception of Food.	
Absorption	Reception into a mouth and stomach
Process of nutrition.	
Deoxidation	Oxidation.

Tissue. Organ. Vessel.—These are comprehensive parts or constituents of the organized structure, as made up of cells ; they are common to all living bodies, and admit of exact definition. There is a difference between the Tissue and the Organ ; one Organ, as the stomach, may contain several tissues. Each Tissue is analyzed into a distinct cell structure, which is its defining peculiarity as regards *structure*, to which there also corresponds a certain kind of activity or *function.* Thus, the nervous tissue is made up of nerve fibres and nerve cells, in a special aggregation ; these are connected with the peculiar activity or function called nerve function, or the manifestation of nerve force.

The view of Plant Life contains the definitions of the *structural parts* of the plant.

Cellular Tissue	Integument (Stomata, Hairs, Glands)
Vessels	Root
Vascular Tissue	Stem
	Leaves
	Inflorescence (Flower, Fruit, Germ).

From the enormous number and variety of plants, a great effort is needed to present these parts in their widest generality ; while the general idea must be accompanied with a classified detail of modifications.

Definitions must also be given of the *processes* of Plant Life.

Osmose	Flowering
Exhalation	Vigils of Plants
Transpiration	Sexual union
Secretion	Impregnation
Irritability and Contractility	Fecundation
Defoliation	Germination
Circulation, sap, capillarity	Propagation.

A set of notions, parallel but more numerous and complicated, belong to the description of Animal Life as a whole. The modifications of the ultimate materials are described as *blastema or matrix*, *crystals*, *protoplasm*, *granules*, *homogeneous membrane*, *vesicles*, *nuclei*, *nucleated cells*, *simple fibres*, *nucleated fibres*, *compound fibres*, and *tubes*. These are compounded into the characteristic TISSUES—*Cellular*, *Adipose*, *Vascular*, *Cartilaginous*, *Osseous*, *Muscular*, *Elastic*, *Epithelial*, *Nervous*. The ORGANS are Bones, Muscles, Alimentary Canal, Respiratory Organs, Heart and Blood Vessels, Sympathetics, Skin, Brain, Senses, Reproductive Organs. The FUNCTIONS follow the Organs; and in several instances, give these their distinctive names.

The Classification of Plants and of Animals gives scope for Definition as applied to the several grades.

5. In these detailed Notions, we have the *analysis* of the Living Organism—Plant or Animal.

An organism is by its very nature a complexity. In a scientific consideration this complexity has to be resolved into the related parts—organs, tissues, constituents. The laws of structure are laws of relations of the parts to each other; and if our analysis has hit the natural partition, it is the basis of our subsequent statements, in propositions, of the natural relations. If the analysis is inexact, no exact propositions can be grounded on it.

Propositions of Biology

6. The Laws and Propositions of Biology differ in their logical character, according as they relate to Structure or to Function.

First, as to STRUCTURE.

The propositions or laws of Structure, affirm co-existence, as order in place, between the different parts of living bodies. Human Anatomy is a vast congeries of such propositions. How far the co-existences are ultimately dependent on Causation, rests with the theory of Evolution. In the meantime, they are to be regarded mainly as Co-existence without Causation.

These propositions may be special to individuals and limited groups of individuals; or they may be generalized over very wide areas. The narrow class is exemplified in human Anatomy, and in all specific descriptions whether of plants or of

animals. High generalities, realizing the scientific ideal of Biology, are not wanting. For example, in Plants—all the parts are homogeneous in structure; or, as otherwise expressed, the flowers are modified leaves; the monocotyledonous mode of germination co-exists with the endogenous mode of growth; flowering plants are generally multiaxial; complexity of structure is accompanied with permanence of form. In Animals, we have the anciently observed coincidence of ruminant stomach, cloven hoof, and horns; the grouping of mammalian characteristics—mammæ, non-nucleated red blood-corpuscles, two occipital condyles, with a well-ossified basi-occipital, each ramus of the mandible composed of a single piece of bone and articulated with the squamosal element of the skull.

Viewed, in the first instance at least, as co-existences without causal connexion, these propositions must be verified by agreement through all nature, and held as true only to the extent observed.

There are numerous and striking co-existences between Structure and External circumstances, the so-called Adaptations of one to the other; but in these there is a great presumption of cause and effect; they furnish the best support to the doctrine of Evolution.

There are likewise laws of causation, more or less traceable, in the operation of all the outward agents. Thus, Heat, Light, Air, and Moisture, are essential or causal conditions of the growth of plants. Light is necessary to the colour of the leaves. The oxygen of the air is an indispensable condition of all animal life. Many other laws of causation are occupied in expressing the agency of different kinds of food, of medicines, &c.

There are laws of cause and effect, in the mutual actions of different organs, in each individual plant or animal. Thus, in animals, the digestive organs affect, and are affected by the circulation, the muscles, and the brain.

7. Next as to FUNCTION, or Physiology.

The propositions here affirm Cause and Effect. The process of Digestion, for example, is an effect of the contact of food material with the complicated alimentary organs. In like manner, every organ of every living being has a function, more or less assignable.

It is a deduction from the permanence of Matter, established since the researches of Lavoisier as a law of nature, that whatever materials exist in plants and in animals, must be sup-

plied as a condition of their growth. Plants being constituted from Carbon, Oxygen, Hydrogen, Nitrogen (in small portions), and Saline bodies,—must find all these elements in the earth or in the air. The animal tissues being highly nitrogenous, animals must have nitrogenous food. The gastric juice contains hydrochloric acid, whence the necessity of salt as an article of food.

8. The law of the Conservation of Force, and all the subordinate generalizations of Molecular Physics and Chemistry, are carried up into Biology.

The law of Conservation holds true in organic changes, and is a deductive key to the phenomena. Every manifestation of force in a living body—mechanical energy, heat, decomposition of compounds,—is derivable from some prior force of exactly equivalent amount.

The laws of Cohesion, Adhesion (in all the forms—Solution. Capillary Attraction, Diffusion, Osmose, Transpiration), Heat, Light, Electricity, and the laws of Chemical combination and decomposition, are carried up into organic bodies. In the present advanced state of knowledge respecting these laws, there are many deductive applications of them to the phenomena of life. The complications of Biology are thus, in part, susceptible of being unravelled by pure deduction.

So far as concerns Force, or energy, in any shape, there is nothing special to living bodies. As regards Collocation, there is the peculiarity of the organized structure. It is not correct to speak of Vital Force in any other sense than the molecular and chemical forces, operating in a new situation. It would be strictly proper to speak of a *Vital Collocation* of elements, under which the molecular forces put on new aspects, although never inconsistent with the primary law of Conservation. Thus the nerve force is something new, not as regards its derivation from an antecedent equivalent of force, but as regards the singularity of the nerve structure, which leads to a new mode in the manifestation of the force.

9. In the department of Function, there are necessarily many Empirical Inductions.

Excepting the deductions from Physics and Chemistry, every law of Biology must be considered as empirical. There are, however, some empirical laws established by an agreement so wide and sustained that they are considered, for the present, as laws of nature. Still, no such laws can be held as

absolutely certain. Notwithstanding the agreement in favour of the derivation of living beings from germs or seed, there is yet a possibility of spontaneous generation.

The following are examples in Plants. Vegetable cells absorb fluids, elaborate secretions, and form new cells; they also *unite to form vessels. Roots absorb material from the* soil, in part by osmotic action. The sap circulates under the influences of heat and light, and the actions going on at the surfaces of the leaves and of the roots. In flowering plants, reproduction is performed by the access of the pollen to the ovules. Fruit succeeds to fecundation. Seeds germinate in the presence of heat, moisture, and air, with absence of light.

There is something very unsatisfactory in the inductions of Vegetable Physiology. Some of them are now obvious results of the law of Conservation; as for example, the influence of Heat at all stages of vegetable growth. The great lack is in the *intermediate steps* of the process; what happens in the interval between the incidence of heat and air in the leaves, and the elaboration of the sap, the setting free of oxygen, &c. But this is the defective part of our knowledge of all the organic processes.

In the functions of Animals, there are numerous empirical inductions. Thus the conditions of Muscular contractions are well known by experimental research; they are the presence of blood, and the stimulus of the nerves. That blood should be necessary is a consequence of the law of conservation; muscular force must be derived from some prior force. That non-azotized materials are sufficient for causing muscular energy could be known only by experiment. Again, the circumstances affecting the heart's action, are empirical inductions; so is the fact that the red corpuscles of the blood carry the oxygen for the tissues. The processes of Digestion are stated in the form of empirical inductions. The same holds of Urination and Respiration. Farther, the multiplied actions concerned in Impregnation, Germination, and Growth, are ascertainable only as empirical laws. All the functions of the Brain and the Senses are given in propositions of the same character.

That exercise (within limits) strengthens all the animal organs has long been established as an Empirical Law. Mr. Darwin is dissatisfied with the physiological reason or derivation of the law; to him, therefore, it remains empirical.

These empirical inductions are to a certain small extent controlled by high generalities, and are in so far derivative. The law of Conservation is a check upon many of them; and

the special laws of Molecular Physics and of Chemistry are seen at work in some. But in such a process as Digestion, the recognized physical and chemical actions are thwarted by deeper forces, of which we have only an empirical statement. The most potent instrumentality of deductive explanations at present known is that furnished by the researches of Graham on Transpiration, Diffusion, Osmose, and Capillarity.

Animal Mechanics, and the propulsion of the fluids by the heart's action, are susceptible of a complete deductive treatment, through the applications of Mechanics and Hydrostatics. This is well exemplified by Dr. Arnott, in his 'Elements of Physics.'

Logical Methods of Biology.

10. In Biology, the facts are open to Observation and to Experiment; although with some limitation owing to the peculiarities of the living structure.

The difficulties attending the observation of living beings are greatly overcome by such instruments as the microscope, stethoscope, laryngoscope, ophthalmoscope, &c, and by the chemical examinations of the various products. Accident sometimes lays open the interior, as in the case of Alexis St. Martin, through whom was obtained invaluable results as to digestion.

11. Through the variety of the cases presented by Biology, there is great scope for elimination by the methods of Agreement and Concomitant Variations.

The means of varying the circumstances by the comparison of instances, agreeing and yet disagreeing, is very extensive. From the number of different vegetable and animal species, each structural peculiarity is presented under the greatest possible variety of accompaniments. And this is only one part of the case. In every individual there is scope for additional comparisons in the different stages of its existence, the method of Embryology. Lastly, the occurrence of monstrosities still farther contributes to the desired variation of circumstances. In these three ways, the opportunities of plying the Methods of Agreement and Concomitant Variations are exceedingly multiplied.

Thus, an examination of the structure of the eyes, in their rudimentary types in the lowest animals, and in their successive phases of growth in the higher, has both suggested and

proved (as some believe) that an eye is a modified portion of the skin.

Mr. Owen enumerates *seven* different modes of carrying out comparisons of the animal structures (Vertebrate Animals, Vol. I. Preface).

The use and limits of the Deductive Method in Biology have been sufficiently adverted to in previous remarks. Some notice may be taken of the applications of Chance and Probability.

12. There are many biological conjunctions of wide, but not of uniform concurrence. Such cases must be dealt with according to the rules for the Elimination of Chance.

When a concurrence, although not universal, is, nevertheless, more frequent than chance would account for, we are bound to recognize a natural tendency, or some law of nature liable to be defeated by other laws. For example, the concurrence of superiority of mental power with superior size of brain, although liable to exceptions, is yet very general, and far more than chance can account for. Hence we must regard this as an established law, with occasional liability to be defeated. We are not at liberty to predict it of every instance, but only with a probability proportioned to the observed frequency as compared with the failures.

13. It is a result of the great complicacy of vital processes, that many inductions are but approximately true; and, therefore, are to be reasoned on according to the principles of Probable Evidence.

The prevalence of approximate generalizations is a mark of the increased complicacy of the Biological processes, as compared with the processes in Physics and in Chemistry.

The best that can be done, in this state of things, is to obtain statistics of the actual occurrence of certain conjunctions. There is a large department, of modern creation, termed Vital Statistics, which enables us to reason on vital phenomena with the degree of probability belonging to each case. It is thus that we can infer the proportions of mortality at different ages, and the proportion of male to female births. When Agricultural Statistics shall have been continued for a sufficient time, the recurrence of good and bad harvests will be capable of being stated with numerical probability.

14. Many of the propositions of Biology are defective in numerical precision.

In Physical and Chemical facts, it is usually possible to measure numerically the degree of the qualities. Thus most of the properties of a mineral can be stated with numerical precision; others, as colour, and fracture, can be referred to a known type. But when we say a certain amount of exercise strengthens the organs, while a greater amount weakens them, we leave the estimate very vague. Change of air is said to invigorate the powers, but there are no precise reckonings, either in the general or in particular cases, of how much invigoration may be expected from a definite change. So, the influence of altered circumstances on breeds and on races is given in vague indeterminate language, and must be taken with great latitude.

Hypotheses of Biology.

15. The character of the science requires the utmost aids that can be afforded by well-contrived Hypotheses.

Biology has all the difficulties of Molecular Physics and Chemistry as regards the impalpable nature of the constituent parts in living bodies, and its own additional complications from the organized structure.

The hypotheses of Biology are of all the varieties enumerated in the general chapter on the subject (INDUCTION, chap. XIII.). Some assume a real cause, as the Development Hypothesis; others assume unreal or unknown agencies, as the supposed adherence to Type or plan; a third class would claim to be Representative assumptions.

Of the first class, we may cite, as instances involving the smallest amount of peril in the assumption, the unverified deductions from general laws of the inorganic world, such as the molecular and chemical laws. These powers of cohesion, adhesion, solution, osmose, &c., are assumed as operating in the living body, but the deduction from them is not sufficiently exact to be fully verified. Hence there is much that is hypothetical in the theories of oxidation, of animal heat, of secretion, &c. From the known chemical inertness of Nitrogen, Mr. Herbert Spencer draws some remarkable inferences in explanation of the vegetable and animal processes (Biology, I. 8).

Development Hypothesis.—This renowned speculation, with all its boldness, has the characters of a legitimate hypothesis; it assumes a real agency, a *vera causa*; its difficulties lie in showing that the supposed agent is equal to the vastness of the results.

Properly speaking there is no rival hypothesis. The Special-Creation view is a phrase that merely expresses our ignorance. Its power of explanation is confined to making a comparison; it assigns to the living species that have successively appeared in the course of ages the same mode of origin as the earliest species of all, and as the whole framework of the universe; an origin that must for ever be inconceivable to the human mind. As the physical theorists who speculate upon cosmical development—the formation of suns and planets—start with the assumption of matter spread out over a great amplitude of space, and coming together by gravity, so the biological theorists assume a primeval start, either of living broods, or of matter ready to become organized under particular circumstances. Now the value of any scientific explanation of life is measured by its capability of tracing the whole of organized nature to the fewest primitive assumptions.

The modification of plants and animals in the course of generations is a fact. It happens even in the same external circumstances, while under alteration of circumstances, the changes become vastly greater. Now, if any means can be assigned whereby some of the modified forms are kept alive while all the others perish, the deviations are rendered permanent. Mr. Darwin provides an instrumentality of this nature in what he calls Natural Selection, or the preservation of the fittest in the struggle of life. It has been his endeavour to accumulate a vast multitude of facts showing the principle in operation, many of them inexplicable on any other supposition. Herbert Spencer, Huxley, Hooker, Wallace, and others, have contributed to the support and elucidation of the hypothesis.

The occurrence of allied species in the same geographical area, and the wide differences in character of the species in localities widely apart, are adapted to the doctrine of development and not to any other view as yet provided. Again, says Mr. Darwin—'How inexplicable is the similar pattern of the hand of a man, the foot of a dog, the wing of a bat, the flipper of a seal, in the doctrine of independent acts of creation! how simply explained on the principle of the natural selection of successive slight variations in the diverging descendants from a single progenitor!' In the course of time and change, certain parts originally useful have become superfluous; and their retention in the useless condition is intelligible only on a hypothesis of descent.

So long as the Development Hypothesis tallies with a very

large number of facts, and is not incompatible with any, it is a legitimate and tenable hypothesis; and its worth is proportioned to the extent of the phenomena that it explains, compared with those that it fails to explain.

Hypothesis of Reproduction.—The reproduction of each living being from one or from two others, through the medium of a small globule which contains in itself the future of a definite species, is the greatest marvel in the whole of the physical world; it is the acme of organic complication.

Mr. Herbert Spencer and Mr. Darwin have recently promulgated hypotheses to represent this process. (Spencer, Biology, I., 253; Darwin, Domestication, II., 357). The two views have a good deal in common, and might be taken together. Mr. Darwin's, however, ventures farthest, and may be here quoted as exemplifying a biological hypothesis. He prepares the way by generalizing all the different modes of reproduction—whether unsexual or sexual. The unsexual modes, as buds and fissure, are to be held as identical with the processes for maintaining each organ in its integrity, for the growth or development of the structure, and for the restoration of injured parts. And it seems to be a tenable supposition that the sexual mode of reproduction is a mere modification of the same general fact.

The hypothesis then is that each egg, or seed (of the female) and each spermatozoon, or pollen grain (of the male) is already a vast aggregation, a world in itself. It is made up of a host of smaller bodies, which may be called gemmules, with all the properties of growth or reproduction commonly attributed to cells in general; this host is different in each species. For every separate part of the animal or plant to be formed, down to a feather, there are distinct gemmules of the type of that part, and unfolding to produce it by ordinary growth. Every animal contains circulating through it the undeveloped gemmules of all its organs, and parts of organs; a complete set is bound up in the ovum of the animal (or plant), and by due expansion reproduces the new individual complete at all points. Something must be assumed as determining them to fall into their places; but that there is no absolute fixity in this respect, Mr. Darwin shows by the frequent occurrence of misplaced organs; this, he thinks, favours the view of the multitudinous gemmules, and refutes any hypothesis of a formed microcosm existing in the seed, to which supposition there are many other hostile facts.

To grasp, reconcile, and generalize the facts, is an ample

justification of this bold venture; by the nature of the case, we can never hope to penetrate the precise operation, nor yet to arrive at a supposition that shall exclude every other. It is, however, an important appendage to whatever hypothesis may be formed of the great vital fact named Assimilation.

CHAPTER V.

LOGIC OF PSYCHOLOGY.

1. Psychology, or the Science of Mind, comprises both Mind proper, and its alliance with Matter, in the animal body.

Definition of Mind.

2. The ultimate antithesis of all knowledge is called the antithesis of Object and Subject.

The object world coincides with the property called Extension; whence the Subject, or Mind, is definable by antithesis as the Unextended. A tree is extended; a pleasure, a thought, a desire, have nothing in common with extended things.

3. By the method of Particulars, Mind is definable as possessing the three attributes named Feeling, Volition, and Intellect.

Feeling is exemplified by pleasures and pains; Volition is action prompted by Feelings; Thought, or Intellect, contains the processes known as Memory, Reason, Imagination, &c.

All our emotions are included under Feeling; our sensations are partly Feelings and partly Intellectual states.

The positive definition of the Mind is also a Division, and must conform to the laws of Logical Division.

Concomitance of Mind and Body.

4. To the Definition of Mind, we must add the Concomitance of the Body.

The concomitance of Mind and Body is a conjunction altogether unique. The extreme facts of human experience—the subject and the object, mind and extended matter—are found in union. We cannot say with certainty whether the union is

a case of causation, or a case of co-inhering attributes. It stands apart.

5. The union of Mind and Body must hold throughout.

While many, from Aristotle downwards, have held that portions of the mind are unconnected with bodily processes, no one denies that mind is to some extent dependent on the body. But all have failed in every attempt to draw a line between the functions that are dependent, and those that are supposed independent of bodily organs.

6. The concomitance of the two radically distinct phenomena gives the peculiar characteristic of the science. Every fact of mind has *two sides.*

Every feeling has its mental side known to each one's own consciousness, and its physical side, consisting of a series of physical effects, some superficial and apparent, others deep and intricate.

It depends upon circumstances whether, and how far, these physical adjuncts should be brought forward in the scientific exposition of the mind. On the one hand, if they are unvarying in their concomitance, they can hardly be excluded without impairing our knowledge of the mental part. On the other hand, it is a bare possibility that the mental phenomena, being radically distinct and unique, may be studied better by making entire abstraction of the physical accompaniments. Moreover, much depends upon the degree of insight actually possessed respecting the nervous system and the various organs related to the mind. It might be expedient at one stage of knowledge to drop these from the view, and at another stage to take them up.

In point of fact, until the present century, only a very small number of philosophers gave systematic attention to the physical implications of mind; the chief being Plato, Aristotle, Hobbes, and Hartley. In spite of the crudity of their knowledge of physiology, they all (with perhaps the exception of Plato) gained most valuable psychological hints by means of that knowledge. The physiology of the present century having placed the whole subject on a new vantage ground, the attention to the physical side may be expected to be much more rewarding.

Thus, on one side, Psychology is a department of Animal Biology, and subject to biological laws. The all-pervading law of Persistence of Force extends to the physical concomi-

tants of mind, and is pregnant with consequences of the utmost practical value.

On the other side, Psychology presents a unique phenomenon—individual self-consciousness—to which there is no forerunner in any of the previously enumerated sciences. Still, the methods and spirit of scientific enquiry, as exhibited in these other sciences, are of value in the study of mind in its psychical side. States of consciousness have degrees of intensity and duration; they are single or compound; they aid or thwart one another; they have their laws of emergence, increase, decline; in all which particulars they observe analogies to physical forces; so that the intellectual habits of accurately estimating physical agencies may, with due allowances, be of service in dealing with the complications of mind.

The two-sidedness of the phenomena appears in language. The terms of mind had all an objective origin; and, while some of them have now an almost exclusively subjective meaning—as pleasure, pain, feeling, thought, sweetness, fear, conscience, remorse,—others have also an objective reference, as shock, emotion, excitement, avidity, irritation. In these last, the language is ambiguous; we cannot always tell whether the physical or the mental is aimed at. There is, morover, a liability to represent the mental fact as a physical fact.

Other Notions of Psychology.

Consciousness.—The most difficult word in the human vocabulary. It concentrates in itself all the puzzles of metaphysics. If it were strictly synonymous with Mind, it would be defined accordingly. But the object, or extended world, is inseparable from our cognitive faculties; so that a word that expresses every conscious state whatever is wider than mind, strictly so called; it comprises both matter and mind. Hence, if 'consciousness' be the name for all sentient states, it is the widest word that we can employ, in fact, there is no meaning corresponding to it; like Existence, it is a fictitious addition of the two highest genera. To state these separately, we must have the double epithets Subject-consciousness and Object-consciousness; which, however, give only the meanings—Object and Subject.

Sensation.—A word with several distinct meanings. In the first place, it may either cover the physical operations connected with the exercise of our senses, or it may be restricted to the purely mental state arising therefrom. In the next

place, inasmuch as the senses give us feelings in the purest form (pleasures and pains) and also intellectual discriminations, the ground work of our ideas,—sensation may be used for either class. In the third place, there is a contrast of Sensation with Perception, or between the *immediate effect* on the mind, and the associated effects; colour and visible magnitude are sensations, distance and true magnitude are perceptions.

The special modes of sensation, together with muscular feeling, are ultimate states of the mind, to be defined solely by individual reference. Resistance, Motion, Warmth, Digestive Sensibility, Taste, Smell, Touch, Hearing, Sight,—as states of feeling, must be known by independent experience.

Emotion.—The emotions are a department of the feelings, formed by the intervention of intellectual processes. Several of them are so characteristic that they can be known only by individual experience; as Wonder, Fear, Love, Anger. These stand very near the ultimate elements of human feeling. Many, however, are evidently derived; such are, in an eminent degree, the Æsthetic and the Ethical emotions.

Phases of *Volition.*—The definition of the Will, or Volition, is a part of the definition of mind as a whole. Will, as contrasted with Feeling, is a unity, indivisible. Yet, there are various aspects or modifications of it, that receive names. *Motive* is the feeling that prompts the will in any one case; the motive to eat is the pain of hunger, or the pleasure of eating, or the pain of defective nutrition. *Deliberation* supposes conflicting motives. *Resolution* is a volition with the action adjourned. *Desire* is ideal volition, either as preparatory to the actual, or in lieu of it. *Belief* is preparedness to act, for a given end, in a given way.

Intellectual States.—In the Intellect, we have three fundamental processes—Discrimination, Similarity, Retentiveness or Revivability; all requiring actual experience in order to be understood. *Discrimination* is another word for the fundamental fact called Relativity and also Contrast. *Similarity*, or agreement in difference, is a distinct fact of the mind; the sensibility corresponding to it is unique; and it is one of the most iterated of human experiences. *Retentiveness* and *Revivability* describe a great characteristic of our mental nature, for which we have other designations, as *Idea*, *Memory*, *Recollection*; it can be defined only by reference to actual experience; although the figurative words—retention, revival, resuscitation, seem to be a definition by the medium of other notions.

The complex intellectual faculties—Reason, Imagination, &c., are defined each by its proper department of exercise; thus, Reason is the power of drawing conclusions from premises, or the scientific faculty. To this definition may be appended, as a real predicate, the derivation from the ultimate intellectual elements just named.

Psychology contains scope for Classification, both according to Logical Division, and according to Ramification or Composition. The ultimate sensibilities—namely, the Senses, the elements of Intellect, and the Simple Emotions—are classified as genera and species, and according to Logical Division. The compound faculties and sensibilities, as the popularly named Intellectual Powers, and the Complex Emotions, are classified solely by Ramification; their classes do not comply with Logical Division.

Propositions of Mind.

7. The complexity of many of the Notions of Mind gives rise to Essential Predications.

Mind itself being defined (positively) by the union of three distinct and irresolvable characteristics, there may be propositions affirming the concomitance of these three facts; as Feeling is accompanied with Volition and with Intelligence. When we say that Mind (as a whole) feels, wills, remembers, we give a verbal or essential predication.

So with many other notions. Such simple feelings as fear, love, anger, if defined, would have a plurality of circumstances. That such circumstances are united, may be a real predication; but when any one of them is predicated of the name, the proposition is essential. 'Anger makes one delight in retaliation' is a purely verbal predication.

Our common talk on mind is full of Essential propositions. His vices were condemned, his virtues praised. Prudence keeps a man out of difficulties. The strongest motive determines action.

8. The conjunction of Mind and Body is a real predication; it being understood that the definition of Mind is restricted to subjective facts.

This holds throughout the detail of feelings, volitions, and thoughts. When the name for an emotion is the subject of a proposition, and the physical accompaniments are affirmed, the predication is real:—'Fear depresses the vital organs' is

an affirmation of concomitance. 'The hope of the reward quickened his speed' conjoins a motive to the will (a feeling) with the bodily part of a voluntary act.

9. The three leading functions, given as the Definition of Intellect (Discrimination, Agreement, Retentiveness), are unfolded in predications.

That Mind discriminates is an Essential proposition; yet the full account of the fact of Discrimination, Relativity, or Contrast, demands numerous propositional statements, many of them real. Not to re-iterate the double-sidedness of every mental fact, the conditions, circumstances, and limitations of each of these leading properties are enounced in propositions that are in no sense verbal.

(1) Thus, we speak of the *law* of *Relativity*, expressed as the concomitance of consciousness with change of impression. This is the general statement; and constitutes a real predication by virtue of the distinctness of the two facts—change of impression (physical, in great part), and consciousness (strictly mental).

(2) *Retentiveness*, *Revivability*, *Contiguous Association*, are names for a fundamental property of mind, which in its exposition takes the form of a law. A certain condition or situation has to be assigned (the reception of present impressions), and to this is attached as a real predicate, the property of being retained, revived, remembered. The various modifying circumstances (engagement of attention, physical vigour, &c.) are real propositions in subordination to the main principle: It is a grand generalization, resuming, explaining, and rendering precise the *media axiomata* of acquisition, as regards intellectual growths, emotional growths, and volitional growths, Under it are given numerous affirmations as to the derivation of complex phenomena from simpler, the unfolding of thoughts and emotions, and the evolution of the mature mind from its primary elements. This is commonly called the Analysis of the Mind. The proof of such assertions rests partly on the consciousness of the hearer, and partly on indirect reasonings. Thus, the proof that Beauty is a compound, and not a simple Emotion, is that we can consciously identify its constituents. The same with the Moral Sense. The indirect proofs are, the absence of the Feeling prior to certain opportunities of mental association. (See § 12.)

(3) The Law of *Similarity*, or Agreement in Difference, is, for the same reasons, an inductive generalization of real

concomitance. 'Present states of feeling, &c., tend to revive their like among former states, notwithstanding a certain amount of difference.' As before, there are required many subsidiary propositions to express all the qualifying circumstances of this wide generality.

Another important law of the mind is sometimes described as the law of the *Fixed Idea*, namely, that ideas tend to act themselves out; as when the sight of yawning makes us yawn, merely by giving us the idea of the act.

10. There may be laws of the rise, continuance, and subsidence of Feelings.

The connotation of each distinct mode of feeling, whether sensation or emotion, indicates both its character as feeling, and its mental antecedent. The laws connecting mind and body, predicate its physical side; the laws of Relativity and of Retentiveness contain additional predicates. To all these may be added inductions as so the rise, continuance, and subsidence of Feeling; which laws, like every other, have a physical side, and may possibly, on that side, be generalized into still higher laws.

Like all sciences where simple elements contribute to form compounds, Psychology contains affirmations respecting the *composition* of feelings and other states. The assertion is made, for example, that Beauty, Conscience, Imagination, are not simple facts, but are compounded of certain assignable elements.

Among the ordinary predications respecting living beings, we may mention the passing of the various capabilities into action. This extends to mind. I walk, speak, reason, wonder, desire, &c., are examples; to all such belongs the reality of predication.

Logical Methods of Psychology.

11. In Psychology, special importance attaches to the ultimate *Analysis* of the phenomena.

In all sciences, we desiderate an accurate and thoroughgoing analysis of the phenomena. It is only an ultimate analysis that can be the groundwork of the most general propositions respecting them.

In proportion to the difficulty of ascertaining and proving the facts in detail, is the value of an ultimate analysis, whereby we can reduce to a minimum the number of independent

assertions. When we know the component parts of an Emotion, for example, Beauty, the Moral Sentiment, or Veneration, we can apply our experience of the parts to correct and confirm our experience of the totals.

12. The proof of a Psychological Analysis is (1) the feeling of identity between the compound and the parts. This must be a matter of individual self-consciousness.

That the Moral Sentiment contains a feeling of obedience to authority, under dread of punishment, is proved by each one's being conscious of the presence, in the compound, of that special element.

13. An Analysis is proved (2) by the identity of the consequences and collaterals of a feeling. This will afford an Objective proof.

That the Religious Sentiment contains an element of Fear, is proved by identity in the Expression and the Actions dictated by the state.

14. The greatest difficulty is felt in establishing the sufficiency of an Analysis.

This is a difficulty in all cases where there is great complexity in the phenomena. We may identify the presence of certain elements, without being able to show that these are the whole. Where the quantity of the elements can be measured, as in Chemistry, we can prove the analysis by casting up their sum. Where quantity is not exactly estimable, as in many biological facts, and in nearly all psychological facts, this check is indecisive.

For example, some have maintained that Benevolence is exclusively made up of self-regarding elements. Others, while admitting the presence of these elements, deny that they account for the whole. Owing to the vagueness of our estimates of quantity in mind, the dispute cannot be decided by a process of summation in ordinary cases. We must proceed by varying the circumstances, and by finding instances where self-regarding elements are either wanting, or so small in amount, as to be obviously unequal to the effect produced. Such an instance is found in the pity called forth by the punishment of great criminals.

15. The Inductions of Mind bring into play the Experimental Methods.

The great Law of Concomitance of Mind and Body must be proved by the Method of Agreement. We must show that the whole of the facts of mind—Feelings, Volitions, Thoughts, are at all times accompanied by bodily processes. The case has something of the peculiarities of the Law of Causation. We can prove the concomitance in a vast number of cases; while in many mental exercises, as in meditative reflection, the physical processes almost escape detection from their subtlety. These instances, however, although unable to confirm the proposition, are not opposed to it; and they do nothing to invalidate the force of the unequivocal instances.

We can do more than establish a law of concomitance of mind and body generally. We can, by the methods of Elimination, ascertain the exact bodily processes connected with mental processes. On this determination, we can bring to bear all the Experimental Methods.

The Law of Relativity is established by Agreement, and, in a remarkable manner, by Concomitant Variations.

The Intellectual Laws, called Retentiveness and Similarity, are established, both in general terms, and as respects their peculiar conditions, by all the methods.

16. From the circumstance that, in Psychology, we have attained to laws of high generality, there is great scope for the Deductive Method.

While every one of the great laws above enumerated is fruitful in deductive applications, the instance that perhaps best exemplifies the Deductive Method of enquiry, considered as a supplement to Induction, is the Law of Conservation or Correlation, applied to Mind, through the physical supports. By this law, every mental act represents a definite, although not numerically expressible, physical expenditure, which must be borne by the physical resources of the system. The deductive consequences of this fact are innumerable. A few instances may be briefly suggested. Great mental labour or excitement is accompanied by corresponding physical waste, which is so much subtracted from the total of the physical forces available for the collective necessities of the system. Again, great expenditure in one mode of mental exertion, if not at the expense of the more properly bodily functions, is at the expense of other mental functions; and so on. Now to such cases, we may apply the deductive process, in all its stages; there is a prior Induction, there may be a process of Calcula-

tion so far as the case admits; there should be a Verification, both from isolated facts and from empirical laws.

These Deductive applications are a valuable check upon the loose empiricisms so abundant in the treatment of mind, and are the best testimony to the use of a science of psychology, in spite of its imperfections. There are empirical generalizations on the points just alluded to, namely, the incompatibility of great expenditure in one direction of effort, with great expenditure in other directions. Now, by the Law of Conservation, such empiricisms receive their definite limitations, and the exceptions are fully accounted for.

17. The Psychological mystery of the union of Mind and Body is the severest test of logical Explanation.

Enough was said in this head, under the chapter relating to Explanation.

Empirical and Derivative Laws in Mind.

18. There are in Mind many Empirical Laws, but, as a consequence of the attainment of high generalities, there are also Derivative Laws.

From the complication of the physical adjuncts of mind, considered as the culmination of Biology, we may expect many of the Inductions to be purely empirical, and as such narrowly limited in time, place, and circumstances.

The phenomena of Dreaming can be stated only as Empirical Laws, with a certain aid from hypothesis.

We have only pure empiricisms to express the operation of stimulating drugs upon the emotional states; whereas the laws that state the operation of food or nutriment can be derived.

Hence, a very great number of the inductions of mind may be traced as Derivations of these higher laws, whereby they attain a greater certainty and compass of application. All the rules for aiding memory are easy deductions from the great law of Retentiveness. The effects of Novelty, and Contrast, are derived from the Law of Relativity.

Strictly speaking, the supreme laws of mind—Relativity, Retentiveness, Similarity, &c., are but a high order of empiricisms. They are not ultimate laws of nature, like Gravity and the Persistence of Force. They are, however, exhaustively verified through the whole of mind; and are

applicable in accordance with the extent of their verification. We properly treat them as the highest or ultimate laws of the department, and employ them deductively in tracing out derivative laws.

Hypotheses in Mind.

19. The principal examples of Hypotheses, in the logical sense, are to be found in the great problems of analysis—namely, Innate Ideas, External Perception, and the Will.

Perhaps the instance most in point is Perception. On this subject, there prevails the assumption of an independent material world and a series of independent minds, brought into mutual contact; an assumption that has the great recommendation of easily and simply expressing all the common phenomena. It has, however, the serious drawback of being self-contradictory; whereas the view that avoids the contradiction is lumbering and unmanageable in its application to express the facts, and hence the backwardness to receive it, as a substitute for the other.

This is an extreme case of a hypothesis believed solely because it squares with the appearances. Not only is there an absence of proof otherwise, but there is flagrant self-contradiction, which ought to be considered as a complete *disproof*.

Among the unexplained phenomena of mind, we are to include Dreaming. One hypothesis on this subject is a real cause, namely, the partial activity or wakefulness of the brain. It is a fact well established that the brain may be either alive or dormant in all degrees. Now if we assume wakefulness *in certain parts*, and dormancy in others, we may account for many of the appearances of dreaming, sonnambulism, and mesmerism. The hypothetical element is the selection of the parts, namely, the senses, and the centres of voluntary movement. The coincidence of the facts with what would follow on this assumption is a considerable probability in favour of the hypothesis.

It is a well-known fact that when a chain of ideas has often passed in succession, and when the last link of the chain is more important than the intermediate links, we pass at once from the first to the last, the others not appearing in consciousness at all. The oblivion has been the occasion of various hypotheses. (1) According to Stewart, the intermediate steps are passed so rapidly as to be forgotten. (2) According to Hamilton, it belongs to the class of latent mental processes

(3) According to J. S. Mill, there is a direct association formed between the first and the last, and the others disappear altogether from the chain. All the three suppositions refer to real agencies; all might operate in the case supposed. Consequently, the decision turns upon whether the effect of any one is exactly equal to the effect observed. Allowing for the standing difficulty of computing mental forces, we may say that, on the whole, the last most nearly coincides with the phenomenon.

The exact character of the human mind at birth is a hypothesis of the second class of scientific hypothesis, a fictitious representation that has no groundwork but fitness to express the subsequent manifestations.

The minds of other human beings and of animals are conceived by us hypothetically as expressing the appearances upon the analogy of our own conscious experience.

Chance and Probability in Mind.

20. The complications of the phenomena of Mind prevent us from attaining laws of universal application. In many instances, we must state our propositions as more or less Probable.

The influence of Education is not in all instances certain. The Law of Retentiveness is sure in its operation, but its various complicated conditions may not always be complied with. A training in good conduct, in most cases, but not in all, makes a good moral character; a training in vice is generally, but not uniformly, perverting. Adversity, in many instances, but not in all, improves the disposition.

LOGIC OF CHARACTER.

21. The SCIENCE of CHARACTER has reference to the *proportionate development* of the sensibilities and powers in different Individuals. It presupposes the Science of Mind.

Human beings in general have certain susceptibilities to Feeling, powers of Volition, and aptitudes of Thought; all which possess degree, and may be unequally manifested in different persons. Hence, an individual mind is not sufficiently described by its participation of our universal mental nature; but must be represented according to the proportionate development of the several Feelings, &c., common to

humanity. We are all liable to Fear; we all possess Tender Affection; but some more, some less.

It is impossible to state these peculiarities of character except in the language applicable to mind universally; or to analyze a character without having first analyzed the mind.

The basis of any Science of Character must, therefore, be the ultimate analysis of the Mind. There should be ascertained, as far as possible, the native and irresolvable Feelings, and the attributes of Volition and of Thought. If a mind were like a mineral, the statement of the degrees of these various fundamental attributes would be the account of a character. But the mind is a thing of indefinite growth, adaptation, acquisition; its first cast is greatly altered before the end; and, as what we usually desiderate is the character of a full-grown man or woman, we must provide an account of the acquired, as well as of the native powers.

The proper view to take of Phrenology is to regard it as a science of Character, accompanied with a theory of external indications. It furnishes a professedly ultimate Analysis of the Mind. It farther endeavours to connect each mental power or susceptibility with a local habitation in the brain, outwardly manifested by the shape of the head. This addition, although highly convenient, is not necessary to constitute a science of character.

22. In the description of characters, there is obviously wanted a *scale of degree*.

The difficulties attending the quantitative estimate of mind are a serious drawback in the science of character. Yet it is impossible not to make the attempt to distinguish more and less in the various mental attributes.

The ordinary mode of procedure is this. In each separate peculiarity—emotional, volitional and intellectual—we form an estimate of the general average of persons known to us. Above and below this average, we use the indefinite adjectives of quantity,—much, great, very great, small, very small, deficient, and so on.

The scale of Phrenology includes a wide range of degrees, probably beyond what can be practically discriminated and agreed upon.

Our most correct appreciations of quantity in mind, rest upon an objective basis. Thus, a slow learner can be compared with a moderate or a quick learner, through the lengths

of time required by each for a given amount of acquisition. This objective method admits of a considerable amount of precision, and is the chief hope of attaining quantitative accuracy in the Science of Mind.

23. The native Elements of Character would be conveniently represented under the three heads—Activity, Feeling (Emotional), Intellect.

The detailed account of these elements is the adaptation of the psychological analysis of the mind, to the statement of the basis of character.

The mental elements might be prefaced by an account of the important physical organs implicated in mental processes, so far as regards their physical characteristics. The Brain, the Muscular System, the Digestive System, &c., of each individual, might be regarded, in the first instance, from the objective side, or as viewed by the physiologist and physician. These organs have all bearings, direct, or indirect, on character.

In recounting the native elements of Activity, Feeling, and Thought, we need to single out for special consideration the Intellectual Retentiveness, as being the expression of the possibilities of growth, acquisition, or education. This is the foremost law of mind, with reference to the moulding or Formation of Character, the means of transforming the various native tendencies into an artificial cast. The educability of a character needs to be looked at by itself; a thing only to be determined by actual experiment of the progress in given circumstances. The schoolmaster, after a certain length of probation, judges whether a pupil will succeed in Mathematics, in Language, or in Drawing.

24. In estimating Character, whether in fact or in expectation, we must never drop out of sight the Law of Conservation, under the guise of the Limitation of the Powers.

The accurate judgment of an individual either as exhibited at any one time, or as regards the possibilities of transformation, must depend upon the precision of our allowance for the Limitation of the Powers. Dealing with persons averagely constituted, we cannot expect a development above average in one region without a falling off in some other; and so on, through all varieties of assumption as to the extent of the powers on the whole, and as to the proportions of each.

25. The subordinate laws of Character are the statement of the operation of Circumstances on the Formation of Character. These must be handled in detail, under the confluent lights of actual experience and of the superior laws.

The circumstances that influence character are various and inexhaustible. They afford a wide exemplification of Induction coupled with Deduction—Empirical Laws transferred into Derivative. They also exemplify the prevailing laxity in the use of the method of Agreement.

The leading circumstances are such as these:—

I. The *physique* of the individual, viewed from its purely physical side; the comparative strength or weakness of the different physical organs. A whole series of consequences to the character follow from the purely physical endowments. Great muscular strength gives a certain direction to the activities and pursuits, whatever be the proper mental tendencies.

II. The physical *treatment* of the system, in all that regards nourishment and the adjuncts of health. The consequences of these are the greater or less total of force, to be distributed among the various functions, including the supports of mind. Climate, town or country life, poverty or affluence, indulgence or temperance, are obvious elements of this computation.

III. Natural *surroundings*, as they affect the mind — the activities, feelings, or intelligence. Differences have often been pointed out as between mountaineers and tenants of the plains, between sea-faring nations and those in the interior of continents, between rural and urban populations. Not much precision has as yet been gained in the expression of those differences. But, if studied by the double method of induction and deduction, they may yield important laws.

It is a clear deductive truth that variety of impressions must enlarge the compass of the intellect. It is not so obvious what will be the effects on the feelings; the æsthetic sensibilities, for example, are not quickened by nature alone; they usually need another stimulus. Incessant familiarity with scenes of grandeur has less effect (on the Law of Relativity) than alternation of these with others of a tamer sort.

IV. Modes of *Industry*, or habitual occupation, give a notorious bent to the character. The effects of occupation or profession have been a subject of frequent observation; many of the consequences being apparent. The soldier, the sailor, the tiller of the ground, the trader, the priest, have each the stamp of their calling.

V. The Surrounding *Society* moulds the individual as to feelings, and as to modes of thinking, in ways too numerous to exhaust, but yet capable of being stated with remarkable precision. The inductive empiricisms on the one hand, and the deductive principles, on the other, conspire to express the remarkable assimilation of the individual to the society; while it is not difficult to point out its limitations, the circumstances being given. The religious, ethical, and political opinions of each person are, in the great mass of cases, the exact reflex of what prevails in the society about him.

VI. The express *Education* given by the schoolmaster should be added to the moulding influence of general society. This element admits of being clearly stated. A people sent regularly to school like the Scotch, or the Germans, acquires a distinct superiority of intellectual and moral character. Under this head, attention must be paid to the educational influence of Institutions; as, for example, an established church.

VII. The amount of Liberty permitted to individuals by the state, and by society, has a vast influence on character. The revolutions that have achieved enlargements of individual freedom, as the Protestant Reformation, are experiments of Difference, showing the impetus given to progress by Liberty.

Political freedom is not exactly the same thing as Self-government, but is not complete without that addition. This too is an instrumentality for moulding the character.

VIII. Many Social Institutions, Laws and Customs, apart from the general fact of Freedom with Self-government, exercise on character an influence that may be studied and assigned. The tenure and descent of Property, the Marriage Laws, improved means of Communication, are obvious instances.

From the foregoing remarks, will sufficiently appear the Notions, the Propositions, and the logical Methods of the science of Character. It will be advisable, farther, to note the heads of Classification; which will serve as an important preparation for the Logic of Politics.

Classification of Characters.

26. The classification of Characters is not a proper classification according to the Natural History mode.

We could not, except by a useless fiction, arrange characters in Orders, Genera and Species. The real distinction be-

tween characters is expressed by the higher or lower degree of some one or more of the ultimate elements of character. And we do not find characters agreeing in a plurality of common attributes, excepting so far as the elevation of one peculiarity implies the depression of some others; and hence we have no basis of generic or specific agreements. The only possible way of giving an exhaustive account of characters is to assume by turns a higher degree of each peculiarity—Active, Emotional, Intellectual, and to state the appearances connected with that; whence by obverse inference we could gather the concomitants of the low degree in each case. Thus, we could indicate the general consequences of an unusual pitch of Natural or Spontaneous Energy; of the Emotional Temperament on the whole, and of any of the special susceptibilities to Feeling or Emotion, as Organic Sensibility, Sight, Tender Emotion.

There is no limit to the possible modes and varieties of character arising out of the conjunctions of different faculties in excess or in defect. These conjunctions, however, must be governed by the laws of their elements; so that their explanation is purely deductive, under the check of actual cases.

27. The details of Character are thus the account of the separate peculiarities, followed by the analysis and explanation of such select conjunctions as are often found, and are of practical importance.

Under the head of *Action*, we have important varieties—as indolence, general or partial, fitfulness of energy, and steady persistence. The *Emotional* character is yet more varied; under it we have the dispositions expressed by sensual, sensuous, sociable, reverential, irascible, egotistical, and so on. The aspects of *Intellect* are more numerous still; general ability, general stupidity, aptitude for language, for science, for art, for business, and many other still more special modes. The attributes involved under Conscience are a very mixed product. That predominance of the Love of Gain—manifested from ancient times by the Jews, and in modern times by the English, and the peoples sprung from them—ought to be traceable to constitutional foundations coupled with circumstances. The sense of Dignity, united with respect for the Forms of Law, and the regard to the Practical and Concrete—as combined in the ancient Roman—offer an interesting subject for analysis and explanation.

The distinctive characters of the Sexes are to be sought by the same analytic procedure. These refer us to physical foundations, as well as to mental elements and to the operation of circumstances.

The problems of character take a practical shape in Education; being an enquiry into the means of moulding character according to prescribed types—Active, Emotional, Intellectual. The experience of the educator is the verification of the deduced maxims.

Under the Logic of Politics, there will be a further occasion for applying the science of character.

CHAPTER VI.

SCIENCES OF CLASSIFICATION.

MINERALOGY.

1. Mineralogy is a Concrete, Descriptive, Classificatory science, referring to the solid inorganic constituents of the globe

A Mineral is defined as a solid homogeneous body, having a definite *chemical composition* and a definite *crystalline form*.

Mineralogy brings forward no new laws or operations. It merely applies mathematical, physical, and chemical laws to the inorganic solid constituents of the globe. Moreover, it is not so much engaged in tracing physical sequences as in arranging and classifying the multitudinous materials we find in the earth's crust. Its laws are laws of co-existence, as Co-inherence of Attribute.

The science of Mineralogy is in close connexion with Chemistry. Had Chemistry attained its present advanced shape at an earlier period, there might have been no separate science of minerals. But for the comprehensive treatment of all material elements whatsoever, under Chemistry, there might be an objection to the exclusiveness of Mineralogy, in refusing to take account of liquid and gaseous bodies, as water and air. Yet, seeing that all these are sufficiently given in Chemistry, there is no need for repeating them in another

science; and Mineralogy retains its special and restricted scope, which is to treat of substances presenting *form* as well as definite composition.

The chief advantage of detaching Mineralogy from Chemistry is to enable minerals to be more fully described in their minute varieties, and to be more comprehensively classified. The separation relieves Chemistry of a burden, and allows a fresh start in the process of classifying.

Definition of a Mineral.—Into the definition of a mineral, two main facts enter, and these dictate the whole plan of the science:—Chemical Composition and Crystalline Form. As regards the first point, minerals are either simple bodies or chemical compounds; and as chemical compounds, they must be homogeneous substances, and not conglomerations of different material like a piece of pudding stone or of granite; such conglomerates are not minerals but *rocks;* quartz is a mineral, gneiss is a rock.

As regards the second part of the definition, minerals have a definite Form; a fact associated with their homogeneous character. The simple substances in their purity, and the definite chemical compounds, when in their highest degree of consolidation, assume definite crystalline shapes; and the occurrence of these shapes is a further guarantee of the homogeneous nature of the material, allowance being made for the property called *isomorphism*, or the existence of similar forms in different materials, which permits of their crystallizing together.

The definition excludes clay, sand, and soils, these being for the most part heterogeneous, as well as formless.

The deposits from organic bodies, as coal, amber, and mineral resins, are improper minerals; they have neither purity nor form.

I. *Arrangement of Mineral Characters.*

2. The exhaustive statement of Characters, in Mineralogy, is substantially the same as in Chemistry.

Under the Logic of Chemistry, we discussed the guiding principle of arrangement of characters, namely, to follow the expository order of the properties: from which was deduced the following sequence.

I. *Crystalline Form.*

II. *Optical properties,* including Refraction, Double Refraction and Polarization; Colour; Lustre.

III. *Specific Gravity.*

IV. *Cohesive* properties, namely, Hardness, Tenacity, Elasticity. To these three heads are reducible Brittleness, Ductility, Malleability.

V. *Adhesion.* This means the cohesive union of different substances, without chemical affinity; the leading cases are solutions, alloys, and cements. It might be the head for entering the composition of those bodies that are treated as alloys and not as chemical compounds. The isomorphous unions are of this nature.

VI. Relations to *Heat.* Rate of Dilatation by increased temperature; Melting and Boiling points; Conduction of Heat; Specific Heat; Radiation, Absorption, Refraction, and Polarization of Heat. This is the exhaustive array of properties having reference to heat; and probably includes more than the mineralogist is ever accustomed to state, they being unknown for the greater number of minerals.

VII. Relations to *Electricity*:—Magnetic property; Conduction or Isolation of Electricity (Frictional and Voltaic); place in the Electric series, from Electro-positive to Electro-negative; place in the Thermo-Electric series.

VIII. *Chemical* properties. The mineralogist is not supposed to transcribe the whole chemistry of each substance. For his purposes a selection is made of chemical re-actions useful in mineral testing.

Occasionally minerals have Taste and Odour.

How far any of these properties can be related, by general laws of Causation or of Co-existence, with any other properties, is an important enquiry falling under Molecular Physics, and is not especially the business of the mineralogiat. Such laws of connexion as may be established, simplify the study of minerals, by making one property the index of another. That there are such laws is certain; several have been noticed in former connexions (Book III., Chap. III. § 3). These laws, however, do not, as yet, dispense with the separate statement of the properties above given, although they may give to several of them a derivative character.

The fact of there being laws of connexion of the properties has an important bearing on the next head.

II. *The Maximum of Affinity of Minerals, as guiding their Classification.*

3. It has to be seen what classification of minerals best complies with the golden rule.

To bring together things that have in common the greatest number of leading attributes, is the first condition of a classification. Now we have above enumerated *eight* different groups of mineral characters; and the question arises, which of all these should be the groundwork of the arrangement into classes.

There are two suppositions that, if true, would facilitate the decision. First, if by the discovery of laws of mutual connexion, any one of the groups of properties were a key to one or two other groups, there would be a reduction of the total number of alternatives. Thus, if Crystallization were related to the modes of Cohesion, or if Electrical and Chemical properties were found to be allied, we should be able to assume one of the allied members as representing both.

Again, if any one group of properties, by intrinsic importance, and apart from the association with another group, had an obvious and marked predominance, such group would be properly chosen to give the lead in the classification. In this point of view, for example, the Crystalline arrangement might be fairly preferred to either Heat or Electricity.

On both grounds, preference is to be given to these two characters; namely, Chemical Composition and Crystalline Form. Accordingly, these are employed as the groundwork of classification. Minerals are first divided according to their Chemical Composition; and farther subdivided according to their Crystallization. In the mineral collection of the British Museum, arranged by Mr. Maskelyne, no other property is employed as a basis of division.

In the older classifications, other characters were made use of. The system of Mohs proceeded on *Crystalline form*, *Hardness*, and *Specific Gravity*. Now, *Hardness*, which we may otherwise express as cohesive energy, must be a result of the molecular forces and arrangements accompanying chemical constitution and crystallization, and, from this circumstance alone, is peculiarly unsuited to be a primary foundation of classes. Again, *Specific Gravity* may likewise be viewed as a result of the molecular arrangements, under which the ultimate particles attain to greater or less proximity.

The arrangement of Weiss is in its chief basis chemical; his primary division into *Orders* is governed by chemical composition purely:—Oxidized Stones, Saline Stones, Saline Ores, Oxidized Ores, Native Metals, Sulphuretted Metals, Inflammables. In subdividing the Orders into Families, he brings into play other considerations. Thus, importance in the com-

position of rocks, or in the geological stratification of the globe, determines such families as Quartz, Felspar, Mica, Hornblende, Garnet. Again, the precious stones, or gems, notwithstanding diversity of chemical composition, have a remarkable agreement in such characters as hardness, tenacity, high specific gravity without metallic aspect, transparency, vivid colours. We may, however, fairly doubt whether either of those two circumstances is enough to justify mineralogists in departing from the arrangement according to the great primary attributes—Composition and Form. In such cases, a supplemental arrangement should be made for the specific object in view, without distorting the one principal scheme. The geologist, to prepare for describing the stratification of the earth's crust, may select, and array for his own purpose, the predominating mineral constituents. And, with a view to the popular interests of the subject, the mineralogist may bring together into one group all the substances that combine the most highly fascinating properties of external appearance.

The arrangement in the British Museum can be briefly referred to, as carrying out the scheme according to Composition and Form.

The first division is into NATIVE ELEMENTS, or Simple Bodies, and COMPOUNDS.

In arranging the *Native Elements*, there is an inversion of the usual order in Chemistry; the Metals precede the Non-metals. This is owing to the predominance of the fact of Solidity in the mineralogical view of the earth's constituents. The native metals, therefore, come first of all; and in deciding their arrangement among themselves, no farther chemical circumstance is taken into account; the reference is solely to Crystallization.

Under the first System of Crystallography, the *Cubic*, are arranged, Copper, Silver, and Gold. Under the fourth System, the *Hexagonal* or Rhombohedral, are the isomorphous metals, Arsenic, Antimony, and Bismuth; and the same forms brings into continuity with these the rare metal, Tellurium.

The Non-metallic native elements are Carbon and Sulphur; Carbon being found in the two mineral forms—Diamond and Graphite.

Compound Minerals.—The native metals occur often as alloys; and these are included with the simple minerals; an alloy is not a chemical compound. The *chemical* combination of the metals takes place chiefly with the non-metals; the prominent instances of combination with other metals, are the

compounds with the Arsenides—Arsenic, Antimony, Bismuth. Accordingly, the Arsenides, &c., are the commencing division of compound minerals; the subdivisions, as in the native elements, being according to form. The three elements Tellurium, Selenium, and Sulphur, are chemically grouped together, under the name 'thionid' elements, and their compounds with the metals—Tellurides, Selenides, Sulphides—are next in order; there being subordinate arrangements according to the crystalline systems, which are nearly all represented. There are also divisions according to still higher compounds, as when Arsenides, &c., unite with Sulphides; which higher compounds succeed in order to the simple compounds.

The next division comprises compounds of the Metals with the non-metallic group—Chlorine, Iodine, Bromine, Fluorine—the 'halogens.' Under these fall certain conspicuous substances—Common Salt, Calomel, Sal ammoniac, Fluor Spar, &c.

The remaining first rank Division of compound minerals is the *Compounds of Oxygen*—a division of enormous extent, and progressive complication. The chief subdivisions are therefore chemical, the distinctions of crystalline form being reserved for the final subdivisions. Commencing with bodies having the lowest equivalents of oxygen—the Monoxides, we are led to the higher equivalents—the Sesquioxides and Binoxides; under each of these heads, the farther subdivision is according to crystalline systems. Next are the Oxygen Salts, of which the Carbonates are an extensive group of minerals, divided by their crystalline forms into Prismatic, Rhombohedral, and Oblique. After these come the Silicates, a large, varied, and important class of minerals, subdivided chemically in the first instance, and by crystalline form in the end. To these succeed Borates and Nitrates. The final groups are Phosphates and Arseniates, which, in consequence of the isomorphisms of corresponding compounds of Phosphorus and of Arsenic, cannot be classified apart.

If it be the fact that the two properties—Chemical Composition and Crystalline Form—have a commanding prominence in minerals overshadowing the others, or else carrying these along with them, the foregoing classification is in the highest degree natural or philosophical, being accordant with the rule of the maximum of resemblance.

4. The Chemical Composition and the Crystalline form also give the proper boundaries of Species.

The question as to the boundaries of species presents no theoretical difficulties on the above scheme. Every native element, and every definite chemical compound, would constitute a well-marked species, an Infima Species, or lowest kind. If the same element, or the same compound, has two allotropic forms, as Carbon, these are distinct mineral varieties, but would not be proper species.

The practical difficulties attending mineral species arise from combinations not chemical, where the elements may be in all proportions; as in the isomorphous compounds, the alloys, and the admixture of foreign ingredients generally. Such instances are proper *varieties*, and receive distinctive names and separate descriptions whenever the difference is of a marked kind.

III. *Classification by Grades.*

5. The Grades in Mineral Classification are used merely for arrangment, and not for shortening the description of Mineral Species.

In the scheme of Weiss, there are three grades—Orders, Families, and Species; an irrelevant and illusive semblance of the classification in Botany and in Zoology, where the several gradations—the Orders, Families, &c.—are each accompanied with a definition, or enumeration of common characters. A Mineral Order, on the other hand—as Oxidized Stones, Native Metals—is accompanied with no definition, and suggests no common characters beyond what is gathered from the name. So with the Families. The family 'Quartz' in the order 'Oxidized Stones' is not defined as a family; there are no characters assigned as common to all the species of the quartz family. There is a *title* OXIDIZED STONES, a *sub-title* QUARTZ; and then commences the enumeration of species; so that each specific description contains all the characters of that species, exactly as if it stood alone in the world. The Gradation, therefore, is a Division, but not a Classification.

In the scheme of the British Museum, the division begins with the dichotomy of Native Minerals and Compounds. The Native Minerals are not again divided formally; they are simply arranged in the order of crystalline systems. The Compounds involve various subdivisions, which could easily be laid out in the tabular form. As there is no systematic treatise on Mineralogy based on the scheme, we do not know

whether the gradation could be properly converted into a system of Orders and Families, in the proper sense, with an enumeration of the characters of those orders and families; but, in all likelihood, no such attempt would be made. Neither Chemistry nor Mineralogy can gain much by straining the parallel of Botany and Zoology in this respect.

IV. *Marking of Agreement and Difference.*

6. The exhibition of Agreement and Difference in Mineral description is gained in the following ways.

(1) By observing a uniform plan.
(2) By proximity of species according to the maximum of agreement.
(3) By select comparisons.
(4) By select contrasts.

From the absence of defining characters in the higher divisions (except as indicated by the significance of the names) the best means of stating agreements is wanting. If the nature of the case does not permit of the operation of giving characters to Orders and Families, we must proceed by other ways.

(1.) A uniform plan in the statement of the characters gives a facility of comparing any one species with any other. This is carried out in works on Mineralogy, although not with all the aids that typography might afford.

(2.) It necessarily follows from a good classification that the species placed in close proximity have the most numerous points of agreement, or the fewest points of difference. When native metals are arranged in crystalline forms, the contiguous species have a very large amount of similarity, and comparatively few dissimilarities. This produces on the reader the effect of a classification by grades, with agreements stated at each grade.

(3) The mind receives great assistance from separate tables of agreements, on select properties. Thus, it is convenient to tabulate the minerals falling under distinct crystalline forms; those having the same specific gravity; the same hardness, &c. This is a great supplemental aid to the mental comparison of individuals.

(4) Select contrasts. When important minerals are nearly allied, and apt to be confounded, they should be brought into direct comparison, through a statement of the agreeing features, and a tabular contrast of the differences. For example, Platinum and Palladium have a very close resemblance, and

might have their agreeing characters given together, and their differences formally contrasted.

V. *Index Classifications of Minerals.*

7. For the ready determining of Minerals, recourse may be had to Index Tables.

The properties apparently most suitable are—Crystallization; Transparency, Lustre and Colour; Specific Gravity; Hardness; Chemical and Blow-pipe re-actions.

Of the two chief modes of constructing an Index—a succession of Dichotomies, and Tabulations—the first is exemplified in Botany, the second seems adapted to the present state of Mineralogy. The thing requisite is to tabulate all known minerals according to every one of these properties, so that when any one property is ascertained, a reference to the table for that property will show what group it belongs to, and thereby limit the search. The discovery of a second property, in like manner, gives a reference to a second table, and reduces the choice still farther.

The first table—*Crystalline Forms*—would be arranged in the order of the crystalline systems, and the important varieties of each, and would also be adapted as far as possible to the indications of the goniometer, which measures the angles.

The *Optical* properties, Transparency, Translucency, Lustre, Colour, might demand several tabulations—one for modes of Transparency and Translucency, another for Lustres, a third for Colours. There are doubts, however, as to the practical utility, for purposes of discrimination, of the table of colours; since, although colour is an important mark in pure substances, the admixture of colouring matters is so frequent as to render the test misleading.

A Table of *Specific Gravities* would be useful as a means of testing. Many substances are well marked by specific gravity. The different varieties of the important group of Dolomites, or magnesian lime stone, are most conveniently distinguished by this test.

Hardness being reduced to a scale of degrees, and being easily tested, is a valuable aid to discrimination; for which end there should be a table of minerals according to degrees of Hardness.

With a view to Blow-pipe and Chemical testing, there are needed corresponding tables for each characteristic appear-

ance; as fusibility or infusibility, solubility in acids, &c. This is merely a modification of the methods of Practical Chemistry.

Each of the Index tables might contain columns for the other important index properties, so as to give all the characters at a glance.

These tables farther point out Agreements among minerals, and furnish one of the modes given for that purpose under the preceding head. Their use in suggesting Laws of Co-existence or of Causation, among the properties of bodies, is sufficient to give them a place among the Arts of Discovery.

BOTANY.

I. *Arrangement of Plant Characters.*

8. The arrangement of the characters of Plants follows the expository order of the parts of the Plant.

This is the principle already exemplified in Mineralogy, and applicable to all sciences of classification.

In a complete system of Botany, the First Division—Structural and Morphological Botany—enumerates the parts of Plants as a whole; giving a generalized and methodical account of all the structures found in all known plants.

Commencing with the constituent *Tissues* of Plants, this division includes—Cells and Cellular Tissue; Vessels and Vascular Tissue; the Contents of the Vegetable Tissues—starch, gum, sugar, oils, resins, &c.; the Integumentary Tissues—as hairs, glands, and other appendages.

Plants differ in the modes of these constituent Tissues. Thus, the *Acotyledons* are cellular plants without vessels, or else vascular plants with scalariform vessels; the *Monocotyledons* and *Dicotyledons* are vascular plants with spiral vessels and stomata.

The *Organs* or parts of Plants are divided into Nutritive and Reproductive. The nutritive are the Root, Stem, and Leaves; the reproductive, the Flowers, and Fruit. An enumeration is given of all the different forms assumed by each organ throughout the entire assemblage of vegetable species. There might be, under each separate peculiarity, a tolerably exhaustive reference to the plants possessing it. By such means the information respecting species is repeated in a different form.

To this department of general Botany succeeds Vegetable Physiology, which, however, has only an indirect bearing on the Classification of plants. Any peculiarity of function in an

individual species would be stated under the organ concerned. Thus, some cellular plants, as *Oscillatoriae*, have undulating movements in the cells; and some, as *Confervæ* and *Diatomaceæ*, conjugate, that is, unite their cells in reproduction, by means of an interposed tube.

The next great division, called Taxological Botany, embraces the Classification of Plants, with the Description of each. The principles of Classification will be considered under the subsequent heads. The order of *Description* is the order of the parts in Structural Botany, as above quoted:—Cellular Tissue, Vascular Tissue, Contents of Cells; Root, Stem, Leaves, Flower, Fruit.

In referring to a work of Botany for the description of any given plant, we shall not find, as in Mineralogical treatises, a consecutive and exhaustive account of characters. Two circumstances stand in the way of such a description.

In the first place, the system of *grades*, which is inoperative in Mineralogy, is thoroughly worked in Botany. Hence to exhaust the characters of a species, we must ascend through all the grades, collecting the characters of each, and uniting them in one series The characters of the 'Common Hawthorn' are distributed (1) under the *species* so named, (2) under the *genus* 'Hawthorn' (*Cratægus*), (3) under the *family* 'Rose' *Rosaceæ*), (4) under the *class*, 'Dicotyledon.' By assembling the common characters of the class, the family, the genus, and the species, in the proper order, we should have a full description of the Hawthorn.

In the second place, most works on Botany do not profess to exhaust the known character of species, or to give under each species the whole of the information that exists respecting it; so that even after collecting the characters from all the gradations, we have not the full knowledge of the species. The reason is, partly, that botanical treatises are usually confined to the humbler function of determining or identifying plants; partly, that the full information, while very voluminous, is seldom asked for; and partly, it is to be feared, from vacillating between the two ends—determination and information.

II. *The Maximum of Affinity of Plants as guiding their Classification.*

9. In considering the characters of plants, with a view to classification, we find the order of description to be also the order of relative importance.

The circumstance that most of all gives importance to a character is the number of other characters that go along with it. Supposing all the characters of equal intrinsic value, any one that represents three others is four times the value of one that represents only itself.

There is a correspondence or concomitance of characters in the fundamental parts of plants—Elementary Tissues, Nutritive Organs, and Reproductive Organs—which facilitates natural groupings. When we assume as a basis any one of this class of characters, we secure at once a large amount of Agreement. Isolated characters, as Colour and Odour, give no help to classification.

Now it is found that the Elementary Tissues are the most important in this view; next are the Nutritive Organs; and lastly, the Reproductive Organs. Certain forms of the Elementary Tissues are accompanied with definite modes in the Organs, both nutritive and reproductive. By the Tissues alone, Plants are divided, in the first instance, into Cellular and Vascular; the Cellular comprising the lower tribes, as Lichens, Seaweeds, and mushrooms; the Vascular, the higher flowerless plants and the flowering plants. Thus, the distinction marks the lower and higher in organization.

In the Nutritive organs, the *embryo* is the part of greatest importance; on it rests the grand ternary division into Acotyledons, Monocotyledons, and Dicotyledons, which represents numerous and important differences, and is, therefore, in the highest degree a natural or scientific division. Second in importance to the embryo, or seed, is the *root*, on which is based a triple division—Heterorhizal, Endorhizal, and Exorhizal. After the root comes the *stem*, by which is marked the great division into Exogenous and Endogenous, together with the farther division into Acrogenous and Thallogenous.

In the Reproductive System, the *stamens* and the *pistils* occupy the first place; these were the chief basis of the Linnean Artificial or Index system. They are the essential organs in the Phanerogamia, or flowering plants; and have an analogue in Cryptogamia, or flowerless plants. Next to these in value is the *fruit*; and after it, the *floral envelopes*; and finally, in flowering plants, are found the *inflorescence* and *bracts*.

Thus, by classing according to the characters that carry with them the greatest number of other characters, there is gained the maximum of affinity on the whole. On the great leading divisions this is effectually secured. The difficulties arise in disposing of the families or Natural Orders, of which a large

number is included in the immediately superior classes (or sub-classes); 66 Natural Orders are contained in the first sub-class of the Dicotyledons (Thalamifloræ). It is impossible to arrange these upon any one principle of succession or contiguity; whence such devices as circular arrangement, double placing, &c. After describing any one Natural Order, Lindley exhibits it diagramatically in the centre of four other orders —right, left, above, beneath—so as to show its alliances on different sides.

A still greater difficulty is presented by the transition classes, which, with reference to the others, are denominated *aberrant*, as departing from a recognized assemblage of characters. At the end of the enumeration of a class is sometimes given detached an anomalous or aberrant member, which, however, by the very fact of its isolation, is a new class. The genus *Spleenwort* (in the FERN family) is a remarkably well-characterized and natural genus; yet a few species are scarcely to be distinguished from some species of Shieldfern and Polypody, except by the *sori*.

III. *Classification by Grades.*

10. Botany is the happiest example of Classification by Grades.

It is a peculiar circumstance in Botanical classification, that the higher divisions are made upon the more fundamental characters (the Tissues); that the next sub-divisions are upon characters next in order of importance (the Roots, &c.) The Natural Orders or Families are characterized by general structure, but especially the Flowers and the Fruit. The characters of the Genus are a continuation of those in the Order. In the Species, the differential marks embrace Stem, Leaf, and Flowers. The tendency of this arrangement is to reduce to comparative insignificance the distinctions of Species.

For practical purposes, great interest attaches to the various products or deposits in plants—starch, sugar, gum, oil, resins, &c. These special products often prevail through Natural Orders, while sometimes they attach to Genera, and sometimes to Species.

The motives for settling the lowest Species, as distinguished from Varieties, were formerly stated. Constancy or permanence of characters is one of the conditions. Thus the Water Ranunculus assumes many striking variations of form, which

have been regarded as specific distinctions; but from their inconstancy, and their dependence upon situation, they are more correctly deemed Varieties. So, Colour is a character that must be generally withheld from specific marks, and given as a variety.

A *plurality* of important characters is the best workable test of a species. The sweet orange and the bitter orange are regarded as Varieties; the lemon is held to be a distinct Species; the points of difference between the sweet and bitter orange are fewer than the differences between the orange and the lemon.

In the inferior forms of Plants, the specific marks are often very limited in number, although they may refer to organs high in the scale. Thus, in the Ferns, the limitation of both genera and species has always been a matter of difficulty. The chief reference is the fructification, or the arrangement of the seed; a character of high fixity and permanence in plants throughout. In grasses too, the limits of the numerous genera are not clearly fixed,—a proof of the fewness of available characters.

The apparatus of Grades necessarily collapses when the organization is not of a sufficiently high order to allow of a series of halting places with important community of attributes. The eight, ten, or twelve steps of descent that may be interpolated in the more elaborately organized *Dicotyledonous* Orders, are reduced to three or four in the Grasses and Ferns; while it may be difficult to maintain even that number in the Fungi, Lichens, and Sea-weeds.

IV. *Marking of Agreement and Difference.*

11. The system of Grades so far provides for the statement of Agreements.

We have frequently called attention to Agreement and Difference as the fundamental facts of all knowledge. The more thorough the provision for exhibiting these two facts, the better will the subject matter be known and understood.

By forming a class, we indicate a community of attributes; and everything should be done to exhibit the Agreement plainly. The tabular form is more particularly suited to characters that can be expressed shortly. It is a grand mistake to suppose that the forms and typography of ordinary composition are suited to the generic and specific descriptions of plants or of minerals. The different heads of the descrip-

tion are seized with difficulty when scattered indiscriminately over the printed lines—sometimes at the beginning, and sometimes at the middle or at the end. Any remark on a character, by way of commentary, or explanation, involving the composition of one or more sentences, should be printed in the compact form of ordinary composition; but the broken, unsentenced description of characters should be exclusively tabular. Such expressions have already the reality of a table, and to deprive them of the form, in order to make them seem *composition*, is to withhold the only advantageous mode of presenting them to the mind. Thus to take the genus Ranunculus described as below* :—

The first sentence, containing a very general remark, may stand as it is, out of the tabular form: 'Annual or perennial herbs, sometimes entirely aquatic;' this should be coupled with the sentence that comes after the description, as to the geographical spread of the genus. The proper descriptive characters are strictly matter for a table, thus:—

Leaves, entire, or more or less divided.
Flowers, usually yellow or white.
Sepals, 5, very rarely reduced to three.
Petals, 5 or sometimes more, each with, &c.
Stamens, usually numerous.
Carpels, numerous, without awns, &c.

As tabular arrangements are hard reading, they may be relieved and lightened by remarks and illustrations, or by adding information that properly takes the form of regular composition.

12. Considerable nicety attends the exhibition of *Differences*, there being, except in dichotomies, no regular method.

Numerous examples have already been given of stating difference by pointed contrast. When more than two things are compared, this is impracticable. Still, the value of the pointed contrast, as appealing to the most fundamental sensibility of the human mind, should never be lost sight of. We may, for example, select for comparison among the numerous

* Annual or perennial herbs, sometimes entirely aquatic. Leaves entire or more or less divided. Flowers usually yellow or white. Sepals 5, very rarely reduced to 3. Petals 5, or sometimes more, each with a thickened hollow spot at the base, often covered by a minute scale Stamens usually numerous. Carpels numerous, without awns, in a globular or oblong head, each containing a single ovule attached near its base.

species of a genus all the twos that are most liable to be confounded.

If the differing species of a genus, or the differing genera of a family, differed throughout; that is, if no two agreed in anything but in the common features of the higher class, the pointed contrast would still be effective. Thus three objects might be contrasted on a single feature, differing in all the three. The actual case, however, is that differing species have many partial agreements; of six species, three may agree in some one point, four in another, and so on. In this state of things, we might carry out a little farther the exhibition of Agreements. We might give Nos. 1, 3, 4, 6, as agreeing in certain features; 2, 4, 5, as agreeing in others. An additional plan is to modify the statement of the generic agreements thus:—Feature A is possessed by all except No. 2; Feature B is possessed by 1, 4, 6; Feature C by 2, 4, 5, 6, and so on (adopting the tabular form).

For example, Lindley constitutes an 'Alliance' or Sub-class, *Berberales*, in which he places seven Natural Orders, distinguished by the Flowers, Stamens, Pistils, &c.; but with partial agreements, thus—

Flowers; regular and symmetrical. All the seven, except Fumariaceæ.

Placenta; axile in four (naming them), parietal in two, sutural in one.

Stamens; alternate in four, opposite in three.

Every device that brings clearly into the view either Agreements or Differences is vital to the understanding and the recollecting of the characters of the various classes. Whenever there is occasion or scope for the exhibition of agreement and difference, the manner of it should be prominent and even ostentatious; often the best course is to detach the statement from the ordinary form of composition, and to put it in tabular array or contrast, as already exemplified.

It is a rule of good exposition not to mix up the description of characters with reflections and theories as to their causes or explanations. This applies especially to all subjects where the descriptions are long and complicated. The following is an improper mixture of the two modes—'The odours of flowers, as well as their colours, vary much. *The sources of odours in flowers are very obscure. They are often traced to the presence of fragrant volatile oils in resins. The effluvia are of such a subtle nature as to elude chemical analysis.* Some flowers are odoriferous only in the evening. This is the case, &c." The sen-

tences in italics should have been withheld until the facts respecting the prevalence of odours had been first stated.

V. *Index Classification of Plants.*

13. From the circumstance of passing through the Linnæan classification, so well adapted to the ready determination of plants, Botany affords the best example of an Index Classification.

We may retain for this purpose the Linnæan system in its literal form; or we may have recourse to the modified schemes of recent Botanical writers. The principle is the same. We commence with certain characters, having alternative modes; and the key or index informs us what classes each mode points to. A second character is then examined, its alternatives found, and the corresponding classes discovered. (See Lindley's Vegetable Kingdom, Bentham's British Flora, &c.)

LOGIC OF ZOOLOGY.

14. The difficulties of Zoological Classification relate to the multitude and the complication of the Animal Kingdom.

The multitude of the objects to be arranged, and the complication of even the lowest forms, distinguish Zoology from all other classificatory sciences. There are certain partial compensations. As compared with Minerals, the organs of Animals present numerous relations of concomitance; and as compared with Plants, the Animal Kingdom falls in a remarkable degree, under a *lineal series,* or consecutive development.

I. *Characters of Animals.*

15. We must look for the characters of Animals in the division of the animal system into constituent Organs.

The Animal, like the Plant, is made up of Tissues and Organs, which have a certain amount of sameness, with variety, throughout the entire Animal Kingdom. The enumeration of these belongs to Biology; Connective tissue, Elastic tissue, Adipose tissue, Cartilage, Bone, Muscle, Nerve, Vascular tissue, Blood corpuscles, &c. In Zoology, however, the Tissues are viewed mainly in the Organs; and Zoological characters are characters of organs. There is not the same use made of distinction of Tissue, as we have seen in Botany. The basis of Zoological Classification is the division of the

Animal system into Organs. These, with their functions, may be variously arranged, there being two natural groups; (1) the Vegetative Organs and Functions (Nutritive and Reproductive) — Digestion, Absorption, Circulation, Nutrition, Secretion, Excretion, Respiration, Generation, Development; (2) the higher Animal Organs — Locomotion, the Senses, the Brain.

In all these various organs, characters may be sought; there being none but what are subject to variation throughout the Animal series. The Anatomy of Vertebrates comprises the following parts:—Skeleton, Muscles, Brain and Senses, Teeth, Alimentary Canal and Appendages, Absorbents, Circulation, Respiration, Urinary organs, Skin, Generative Organs. The Blood is also a source of distinction in the larger divisions—as between Vertebrate and Invertebrate, Warm-blooded (Birds and Mammals) and Cold-blooded (Fishes and Reptiles).

The grand separation, common to all classificatory sciences, between the General and the Special Departments, in the Animal Kingdom, gives birth to the two subjects,—*Comparative Anatomy* and *Zoology*. As in Mineralogy, and in Botany, these should repeat and support one another, giving the same information in two different forms.

The Comparative Anatomy arrangement, besides settling the selection and the order of Zoological characters, is a most powerful instrument of generalization. The exhibition of each successive organ in all varieties and modifications, discloses many aspects otherwise hidden; and places the more general and fundamental peculiarities in a strong light. Much of the insight that we at present possess regarding the brain is due to Comparative Anatomy. Too great pains cannot be given to the perfecting of the Comparative Method; and the grand secret is the lucid presentation of agreements and of differences.

16. There being, in Animals, a number of distinct organs, a search is made for Laws of Concomitance between them.

It is a part of Biology, and an indispensable aid to Zoology, to find out the correspondences or laws of concomitance between the different organs—Moving Organs, Nervous System, Digestion, Reproduction, &c.

These laws occur under various aspects. Some are empirical generalizations, such as the coincidence of the ruminant characteristic with the cloven foot and horns on the frontal

bone. Other coincidences are mutually related, and are part and parcel of the development of the species; as the advance of the brain with the muscular system, the reproductive organs, and the organs generally. The fact of increase of organization as a whole implies laws of concomitant advancement of all the leading organs. The connexion between an animal's organs and its circumstances or conditions of life is not a law of co-existence, but of mutual implication; it does not give us two independent facts, but the same fact on two sides. All references to the *element* of each species—water, air, earth, the body of another animal—are to be held as merely illustrating the nature of the organs.

The best established laws of concomitance in the animal organs, on which depends the existence of a science of Zoology, as distinguished from a Comparative Anatomy of animals, are liable to exceptions. Sometimes a single species will mar the unanimity of an entire Division, like Amphioxus among fishes. It is clear, however, that such exceptions are to be mentioned, and then disregarded. They do not even prevent us from supposing that the characters whose conjunction they violate are united by cause and effect; for although causation permits no exceptions, it may be ocasionally counteracted.

The more we can exhaust the relations of correspondence or concomitance, and the more precisely we can express them, the better are we prepared for the great classifying operation that makes up Zoology. The full import of the remark will appear under the next head.

It might seem superfluous to insist on preserving a regular *order* in the statement of Characters throughout the whole scheme—whether in the Comparative Anatomy or in the Zoology,—seeing no one can follow out comparisons that are not uniformly expressed.

II. *The Maximum of Affinity as giving the Classes.*

17. The choice of Classes follows the maximum of agreements in the several organs.

The existence of Laws of Concomitance indicates the possibility of finding animal groups that agree in two, three, or more organs, or important modifications of organs. The zoologist grasps at this circumstance, in order to form his leading classes.

In appearance, but only in appearance, there is another

principle of grouping. *Some one* organ is chosen as the basis of classification; for example, the Reproductive system, which gives the name to Mammalia. In reality, however, such choice is made not on account of the organ by itself, but on account of the *number* of its *alliances*.

An extreme supposition will place this fact in a clearer light. Let us imagine that every one of the leading organs, or systems,—Nervous, Reproductive, &c.—was wholly unconnected in its modifications with every other organ; that the nervous system might vary through all possible modes without any corresponding variation in anything else. Under such circumstances, we might have a comparative anatomy of each organ, but no concurrence of organs. Zoology would be incompetent and non-existent. The only possible classification would be according to the Comparative Anatomy of the several organs. We might assign a superior dignity to same one organ, as the Brain, and give it a priority in arrangement, and a preference in study; but after the entire animal kingdom had been exhaustively arranged under the comparative anatomy of the Nervous System, the same operation would have to be repeated under the other systems; the work would then be finished; being substantially the present science of Comparative Anatomy, without the relief that is at present afforded, to the overwhelming mass of details, by laws of Concomitance.

Accordingly, the justification of preferring one organ as the classifying basis, is avowedly its *alliances*. The taxonomic value of the 'placenta' in Mammalia is the number of characters that it carries along with it. 'Man, the Apes, the Insectivora, the Cheiroptera, the Rodentia,—are all as closely connected by their *placental structure* as they are by *their general affinities*' (Huxley). The real motive to the grouping is *not* the placental structure, *but* the general affinities.

We may make another illustrative supposition. If all the organs were strictly co-equal in development and in modifications; if the Nervous System, the Muscular System, the Reproductive System, &c, were all modified in strict concomitance, there would be no such thing as a preference organ whereupon to base classification; the Reproductive organs could be no more a clue to the 'general affinities' than the digestion, or the respiration. There would be no mention of a special basis; general affinity would alone be prominent.

It would appear, however, that the constituent systems of the animal organization are not co-equal and concomitant in

their changes; some carry with them more, and some less, of general affinity or concomitance. Taking the whole Animal Kingdom, we find that the *Nervous System* is by far the most important basis of classification; the reason being that the organs generally cannot advance without a corresponding rise in the regulating and co-ordinating organ. There cannot be an extension of the muscular apparatus without an extension of the brain; while the muscular apparatus itself implicates many other parts of the system.

Next to the Nervous System is that part of Reproduction, embracing the mode of *Development* of the animal from the germ upwards. We have already seen how far this governs the divisions and sub-divisions of the Mammalia; their very name is founded on it.

If, for the sake of illustration, it were asked what would be the *worst* organ for classifying upon—the one that undergoes the greatest degree of unconnected or isolated variation,—the answer would probably be the Heart.

III. *Classification by Grades.—Species.*

18. It being assumed that each class is formed on the maximum of affinities, the number of grades is regulated by the occurrence of a succession of suitable groupings.

The grades, or halting-places, are a relief to the burden of numerous common characters; but there is no need to constitute them where the amount of resemblance is inconsiderable.

In the higher Vertebrates, a succession of six, seven, or more grades is admissible and advisable; while the attempt to constitute Natural Orders, Genera and Species, in the Protozoa, is misplaced and savours of pedantry.

In Mammalia, the distinctions of Species may be numerous and important; profound differences separate the Lion and the Tiger, the Horse and the Ass. In Birds, on the other hand, the species often turn upon small and nice peculiarities Of the three hundred species of Parrots, it is impossible that there can be specific differences either numerous or important; the Psittacos erithacus, for example, is distinguished as *grey*, with *tail red!* The domesticated *varieties* of the horse, dog, and cat, have wider differences than many species, or even genera, of the lower animal tribes. The differences between a Negro and a Caucasian (*varieties* of the Species—Man) pro-

bably surpass in number the distinctions between two Natural Orders of Infusoria.

In some cases, there occurs a single character so bold and remarkable as to satisfy our utmost demands for a specific distinction. Such is the extraordinary electrical organ in certain fishes. The species of the Gymnotus named *electricus*, is sufficingly marked by this single feature, in whose presence the describer abstains from all further specification.

IV. *Marking of Agreement and Difference.*

19. Zoology depends greatly on the rule of parallel array for Agreements, and of pointed contrast for Differences.

The characters of classes, high or low, should be thrown into the form most advantageous to the reader, that is, the tabular arrangement, with appended remarks and commentaries in ordinary typography.

For example, the characters of AVES (reckoned sufficient for discrimination, although inadequate as information) are these:—

Reproduction :—oviparous
Respiration :—air-breathing
Heart :—four cavities, as in the Mammalia
Integument :—feathers
Teeth :—wanting ; substitute horny jaws
Locomotive Organs :—the anterior limbs are wings.

Besides these characters much is to be said as to the points of community, in the Nervous System, the Digestive System, and other parts.

For the statement of Difference we may select Mr. Huxley's primary division of Birds into three classes ; an instance where the pointed contrast may be extended to three members :—

SAURURÆ	RATITÆ	CARINATÆ
	Metacarpal Bones	
Not ankylosed	Ankylosed	Ankylosed
	Caudal Vertebræ and Tail	
Longer than body	Shorter	Shorter
	Crest of Sternum	
	None	Present
	Barbs of the Feathers	
	Disconnected	Connected.

There are several other characters of the second and third classes, and no more of the first. Hence, we might have put the first against the two others as a whole, and then worked out the present contrast upon these two.

Not merely in the formal exhibition of generic and specific characters, but in every incidental comparison of one class with another, the statement of Agreements and of Differences should always be clear, emphatic, and ostentatious.

V. *Index Classification.*

20. An Index Classification for Zoology might choose between the two alternatives—the *tabular* and the *dichotomous.*

The Tabular method has already been suggested for Mineralogy, and will again be brought up for Diseases. The Dichotomous method is carried to perfection in Botany.

A tabular plan could be based upon Comparative Anatomy; there being given, under every peculiar mode of each organ, a complete list of all animals possessing that mode. Thus, there would be a table of the species conforming to each grouping of the Teeth, so that the discovery of such grouping in any given specimen would decide the animal as one of the list. A second character being noted as present in the specimen would direct to a second list, where the animal must appear; the choice is now narrowed to such as are common to both lists. A third, and a fourth character, being followed out in the same way, would reduce the choice to still smaller limits; and eventually the enquirer would be guided to the proper Species.

The dichotomous method of Botany, if fully adapted to Zoology, as it might obviously be, would be still better.

The want of an Index is less felt in Zoology because of the better marked specific distinctions, at least until we descend to the inferior tribes, where there are numerous species, slightly marked. It would be pre-eminently necessary for Birds, among Vertebrate animals, and for the Invertebrate Orders generally. It is less necessary for Mammalia, except in a collection of unusually vast extent.

CHAPTER VII.

LOGIC OF PRACTICE.

1. The Practical Sciences are defined by their several ENDS.

Medicine is the practical science having for its end Health. Grammar and Rhetoric have for ends the perfection of the instrument of Language.

2. There is one crowning end, the sum of all other ends, namely, Happiness or Well-being.

People desire Health in order to be happy. There can be no end beyond human enjoyment—the gaining of pleasure and the averting of pain.

3. The final end of all pursuit must be assumed or granted; it cannot be proved.

No proof can be offered of the position that Happiness is the supreme end of human conduct. We must be satisfied with the fact that mankind make it the end. As all proof consists in referring the point in question to something more fundamental, there must be at last something taken for granted on its own account. Such is Happiness, the highest crowning end. Men desire Happiness, either for themselves or for others, as the goal of all endeavour.

4. There is, however, a want of perfect unanimity as to the final end. Some even deny that Happiness is the end; while there may be great difference of opinion as to the nature of the happiness to be sought.

The end set up by some, as the final end of all, is Virtue. To those that embrace this view consistently, there is no reply; there is no possible appeal from a fundamental end.

We may, however, enquire whether any class of persons do *consistently* and thoroughly maintain virtue, and not happiness, to be the sole end of all endeavours. Wherever there is inconsistency, an argument is possible.

Now, in reply to the setting up of Virtue, or mere self-denial, as an end, we may urge, first, that the conduct of mankind shows that, in the great mass of cases, they regard virtue

as a *means* to happiness. The virtue of Howard consisted not in the fatigues and privations suffered from his journeys, and from visiting squalid dungeons; it was in the amount of human misery that he relieved.

Secondly, the position that Virtue is an end is almost uniformly coupled with the assertion that, in the long run, Virtue is Happiness; which is merely another way of assigning Happiness as the end.

Thirdly, the thorough carrying out of the position that Virtue, in the form of ascetic self-denial, which is Virtue dissociated from Happiness, is the ethical end, would be tantamount to abolishing the difference between good and evil, with which virtue itself is identified. Virtue, in the sense supposed, flourishes in misery; the more miserable we are, the greater scope we have for virtue; the more miserable we make other people, the more scope we give them for virtue.

Again, Happiness may be allowed as the end, and yet there may be wide differences of view in the interpretation of the end. The partizans of virtue may re-appear on this ground, affirming that Happiness is only to be found in Virtue or Duty, not in enjoyment and in the absence of pains. The reply proceeds as before; are these reasoners thoroughly consistent with themselves? If they are, they cannot be refuted; if they are not, they may.

Great variety of opinion may be held as to the beings whose happiness is to be sought. Are we to seek our own happiness solely, or the happiness of others solely, or partly the one and partly the other? How far are we to extend our regards—to our own kinsmen, to our fellow citizens, to humanity in general, to the lower animals? In none of these points is argument possible, unless where people are inconsistent, which they need not be. We cannot reason a person into the adoption of other people's happiness as an end, unless such person has already of his own accord embraced some doctrine that involves this, as for example, the profession of Christianity. Neither can we offer any reason for extending sympathy to the lower animals. An education of the feelings is the only mode of enlarging people's sympathies. No man can be argued out of a consistent selfishness.

CHAPTER VIII.

LOGIC OF POLITICS.

1. Politics, in the largest sense, refers to the action of human beings in Society.

The notion of Society can be gained only by each one's individual experience. The first example of it is the Family, which contains a plurality of persons in mutual co-operation, with command and obedience. The earliest notions of authority, law, command, obedience, punishment, superior, inferior, ruler, subject,—are gained from the various aspects of the small domestic circle.

The larger aggregations of the school, village, parish, township, church, &c., repeat all those aspects of the family, while dropping the incidents special to the family.

2. The science of Politics, as a whole, is either Theoretical or Practical.

Under the Theoretical Science of Politics must be described the *structure* or organization of Political Society; this being equally essential as a preparation for the Practical Science. All the leading terms of Politics must be defined; all the parts of the Political system explained. To this preliminary branch, Sir G. C. Lewis applies the designation 'Positive Politics.'

In the second place, the Theoretical Science traces cause and effect in political institutions, as facts of the order of nature; in the same way as Physics and Chemistry describe cause and effect in inorganic bodies, and Biology in living bodies. The theoretical department of Society would state, upon evidence of fact, conjoined with reasonings from human nature, what are the consequences of given institutions. To quote from Sir George Lewis :—

'It assumes that we know what a state is; what are its functions; what are the conditions necessary for its existence; by what instruments it acts; what are its possible relations with other states. Starting from this point, it inquires *how certain forms of government*, and certain laws and political institutions, *operate*; it seeks from observed facts and from known principles of human nature, to determine their character and tendency; it attempts to frame propositions respecting their probable consequences, either uni-

versally, or in some hyyothetical state of circumstances. Thus it may undertake to determine the respective characters of monarchy, aristocracy, and democracy; it may show how each of these forms of government promotes the happiness of the community, and *which of them is preferable to the other two.* It may inquire into the operation of certain modes of preventing crimes—as police,—of criminal procedure, and of legal punishment, such as death, transportation, imprisonment, pecuniary fines,—and it may seek to determine the characteristic advantages and disadvantages of each, in certain assumed conditions. It may inquire into the operation of different systems of taxation—of laws respecting trade and industry—of modes of regulating the currency—of laws regulating the distribution of property with or without will—and other economical relations. It may lay down the conditions which render it expedient to govern a territory as a dependency; or which tend to promote the prosperity of a new colony. It may define the circumstances which ensure the permanence of national confederacies, and it may inquire what are the rules of international law which would tend to promote the uninterrupted maintenance of peace.

'It seeks to lay down general theorems respecting the operation and consequences of political institutions, and measures them by their utility or their capacity for promoting the welfare of the national community to which they are applicable. Propositions of this sort may lead (though not by so direct a road as is often supposed) to preceptive maxims; but they are themselves merely general expressions of fact, and they neither prescribe any course of conduct, nor do they predict any specific occurrence; though, from the generality of their form, they may relate as much to the future as to the past.'

The Theoretical Science of Society is sometimes expressed as the 'Philosophy of History,' or the accounting upon general principles of cause and effect for the actual course of political events, the growth of institutions, the progress and decay of nations. History, in the ordinary signification, recounts these things in the detail; the Philosophy of History generalizes the agencies at work, and endeavours to present the whole as following out certain great leading ideas. A few writers have aimed at establishing such generalities—Vico, Montesquieu, Millar, Condorcet, Auguste Comte, &c.

Practical Politics consists of maxims of political practice. Here we have to suppose an *end,*—the welfare of the community, or any other mode of stating the political end.

This necessarily appears with more or less prominence in all political treatises. Aristotle's work is a search after *the best government.* Machiavel's treatises are preceptive or practical. Locke does not formally enquire after the best constitution,

but under the guise of what is necessary to a state, he insinuates certain political forms, and certain legislative principles.

Sound method requires that a writer should, in the first instance, separate the Theoretical from the Practical.

3. The entire department of Political Science at the present day comprises several sciences.

It has been found practicable and convenient to withdraw from the wide region of human society, certain subjects that can with advantage be cultivated apart, and thus to reduce the complication of political enquiries.

(1) The first of these is Jurisprudence. This is a distinct branch bearing on the *form* of Law, as apart from its substance. It teaches how laws should be expressed, with a view to their satisfactory interpretation by the Courts; it embraces evidence, and the principles and procedure for the just administration of the laws. It does not consider the choice and gradation of punishments, but explains how they should be legally defined, so as to be applied in the manner intended by the legislator.

(2) International law is the body of rules agreed upon by independent nations for regulating their dealings with each other, both in peace and in war. It includes, for example, questions as to the Extradition of Criminals, and the right of Blockade at Sea.

(3) Political Economy, or the science of the production and distribution of Wealth, relieves the political philosopher of a considerable part of his load. The legislation regarding Property in Land, Trade, Manufactures, Currency, Taxation, &c., is guided by the enquiries of Political Ecomony. Within its own sphere, this science has the same logical character as the mother science. It has its definitions, its principles or laws, partly inductive and deductive, and its methods, which are the ordinary logical methods.

(4) Statistics is a branch of the Science of Society, admitting of being cultivated separately. It furnishes the facts and data of political reasoning in the most complete and authentic form.

4. The subjects remaining to Political Science, are (1) the Form of Government, and (2) Legislation on all topics not otherwise embraced.

The different Forms of Government, their precise definition, and their several tendencies, constitute the foremost problem of the political science. The discussion of Monarchy,

Aristocracy, Democracy, enters into every treatise called political.

In immediate connexion with this subject, if not a part of it, is the distribution of the functions of government, into Legislative, Administrative and Judicial; the delegation of the powers of government to subordinate authorities, as in provincial, local, or municipal government.

These subjects are sometimes considered as exhausting the sphere of Politics; but in a very narrow, although distinct signification of that sphere. Thus, Mr Mill remarks,—'To attempt to investigate what kind of government is suited to every known state of society, would be to compose a treatise on *political science at large*.'

It must, however, be matter of enquiry how a government, when constituted, is to discharge its functions. This supposes that the functions are classified and defined; an operation involving one very important enquiry in Politics, namely, the proper *Province of Government*.

There are certain things that Government must undertake, in order to fulfil its primary ends; such are Defence, and the Preservation of Life and Property.

There are other things that government may or may not undertake—as the Support of Religion, Education, Postal communication, the maintenance of Roads, main Drainage, and other works of general utility.

5. The curtailment of Individual Liberty is a necessary effect of government; and the degree of this curtailment is a vital consideration in Political theory.

In order that men may act together in society, each must in part subordinate their own actions and wishes to the general scheme. Obviously, however, individual liberty, which is in itself a chief element of well-being, should be restricted in the least possible degree; and the burden of proof must always lie upon the proposer of restraint.

The Structure of Political Society.

6. The preliminary branch of the Social Science, contains the Definition of Political Society, and of all the Relationships and Institutions implied therein.

This is the part of the subject entitled by Sir G. C. Lewis Positive or Descriptive Politics. It teaches what is essentially involved in the idea of political government. It explains the

necessary instruments of government; as a law, rights and obligations, sanctions, executive commands, and the like. It neither enquires into the operation and tendency of institutions (which is Theoretical Politics), nor urges the preference of one to others (Practical Politics). It explains the meaning of monarchy, aristocracy, democracy, but does not teach which is the best form. It shows what is the nature of punishment, but does not say which punishments are the most efficacious. It expounds the relations of master and free servant, and of master and slave, but does not trace their bearings on the welfare of the parties concerned. It explains the nature of a dependency, without arguing the question—Should colonies have a separate government. It shows what are the acts constituting an exchange, and the difference between barter and a money equivalent, but does not dwell upon the advantages of exchange in facilitating trade. (Methods of Reasoning in Politics, vol. I., p. 54).

The fundamental notions of Political Society—Sovereignty, Law, Command, Duty, Sanction, Obligation—are treated of by John Austin as a part of the special science of Jurisprudence. That these notions are at the basis of Jurisprudence is beyond doubt. Still, in a completely formed Political Science, they would be given once for all at the outset, under the head of the Structure of Political Society, and would need only to be referred to by the Jurist.

7. The very fact of Political Society involves a series of primary notions, forming a mutually implicated, or correlative group.

Government.—This is the essential fact of political society; to define it, or any one of its numerous synonyms—Sovereignty, Authority, Ruler, Political Superior—is to define political society. The definition must be gathered from the Particulars common to Political Societies. It is given by Sir G. C. Lewis, as follows:—"When a body of persons, yielding obedience to no superior, issue their commands to certain other persons to do or to forbear doing certain acts, and threaten to punish the disobedience of their commands by the infliction of pain, they are said to establish *political* or *civil government.*"

Closely examined, this definition contains the very terms to be defined—for example, superior and command—so that it is not a definition suited to inform the ignorant. It is rather of the nature of the first definitions of geometry (Line, Angle, &c.) which do not communicate notions, but employ terms to

fix with more precision the boundaries of notions already gained from experience. We should require, in the first place, to know political societies, in concrete instances; and the definition would teach us the corresponding abstraction or generality.

Austin (Province of Jurisprudence Examined) endeavours to build up the definition from its simplest assignable elements. Starting with Command, he defines this as 'the expression or intimation of a wish, to be followed with some evil, if not complied with.' This involves only such facts of human nature as wish, expression, non-compliance, infliction of evil. In the notion of Command, as thus defined we have nearly all that is signified by Government, Sovereign, Superior, Authority. We have only to specify the persons intimating the wish (to some other persons) and following up the non-compliance with the infliction of pain.

The supposed command is a *Law*. The evil to be inflicted is a *Sanction*, *Penalty*, or *Punishment*. The persons addressed are *Subjects*, *Inferiors*; they are placed under *Obedience*, *Duty*, *Obligation*. The aggregate of persons comprised within the scope of the same commands, is a *Political Society*, a *Community*, a *People*. They are in the *Social state*, as opposed to the *state of nature*.

Moral Right and *Wrong* must be referred to the same complex fact.

8. Government is usually said to have three distinct functions—Legislative, Executive, and Judicial; each one giving birth to a numerous class of notions.

Legislature.—The power of making general commands universally applicable, under given circumstances, is called *Legislation*; it is the most extensive and characteristic function of government. The process is very different under different forms of government. In every shape, there are implied as subsidiary notions—*statute*, and its synonyms, publication or proclamation, enactment and repeal, &c.

Executive, Administration.—Implies performance of the specific acts occurring from day to day, in the exigencies of society—organizing and directing the military force, negotiating with foreign governments, appointing the officials of government, erecting public works, &c. In this function, the government is said to use *ministers*, to issue *orders*, to receive and issue *despatches*, *reports*, to *superintend* all functionaries.

Judicial.—A distinct function of government, usually en-

trusted to a separate class of persons. It supposes impediments to the commands and operations of government, either in the way of misunderstanding, or of disobedience. These are removed by Judicial Institutions, called *Courts of Law*, presided over by *Judges*, said to administer *Justice*, according to a definite *Procedure*, and rules of *Evidence*. The ramified arrangements belonging to these several heads are detailed and defined by the special science of Jurisprudence.

With all varieties of government there must exist these three functions; in rude governments, they are exercised by the same persons; in civilized governments, they are more or less divided between different persons.

9. Under 'Form of Government,' there is a number of structural modes, for which there are specific designations.

The Form of Government brings out the designations Monarchy, Aristocracy, Democracy, Republic, Mixed Government, Balance of Power, Constitution.

The logical division of Forms of Government is into the government of one person (*Absolute Monarchy*) and the government of more than one (*Republic* or Commonwealth). If, in the second alternative, the governing body is small, the government is an *Aristocracy;* if the power is lodged in the majority of adult citizens, the government is a *Democracy*. Such names as Limited Monarchy, Constitutional Monarchy, mean either Aristocracy or Democracy; they indicate the form of monarchy, but the reality of another power. A *Mixed Government* is a mere semblance; some one of the constituents is in point of fact the sovereign.

Aristocracy, where it prevails, makes a division of the people into *Nobility* and *Commonality*. Often the governing body is a *hereditary* nobility.

Representative Government, the growth of modern Democracy, is a leading notion of Political Science. The meaning is that the whole people, or a large portion, exercise the ultimate controlling power, through the deputies periodically elected by themselves. In the ancient republics, the corporate or collegiate action lay with an assembly of all the citizens, or of as many as could be got together.

The operations of corporate government give birth to the political elements expressed by *assembly*, *deliberation* and *debate*, decision by a *majority*, *chairman*, *election*, *suffrage*.

10. The Functions or Business of government introduce many structural elements.

The first function of a political society being *defence*, there is a large institution corresponding, called the War Organization—Army and Navy.

The protection of the members of the society from one another is either by an application of the War force, that is the soldiery, or by a separate force called Police.

These two leading institutions involve many others. An official machinery, or *bureaucracy*, is interposed between the sovereign power and the actual instruments. For paying the cost, there must be a levy of Taxes, with a bureaucracy corresponding.

If the government undertakes public works—roads, bridges, public buildings, means of communication—it becomes a sort of industrial management on the large scale.

The coining of *money* is a proper function of government.

The regulation of bargains and *contracts* of every description, as well as the enforcing of them, is a matter for the state. The marriage contract, in particular, the relations and rights of the different members of the family, are under state control.

A Church Establishment, whether incorporated with the civil government, as is most usual, or existing apart, is a vast social machinery with elements and terms corresponding, all admitting of definition.

11. In a society spread over a wide territory, there must be a division into local governments, duly subordinated to the chief or Central Authority.

This originates the terms *Central, Centralization*, and *Local, Provincial*, or *Municipal* government and institutions. A small locality may represent in miniature nearly all the features of the entire society. The delegation of power to the locality may be small or may be great. Moreover, the Form of Government of the entire society repeats itself in the localities. If the sovereign is an absolute monarch, the local authority is absolute in the local sphere; such is the oriental satrap, and the viceroy of the absolute European monarch.

12. The Province of Government marks the line between *Public* and *Private* management.

The habitual industry or every day avocations of the mass of the people must be left to themselves. Their manner of subsistence, their recreations and amusements, are also their own choice; although governments have often interposed to regulate all such matters.

13. The mutual bearings of Public and Private Institutions are so numerous, that a statement of the Political structure is incomplete without the Private Institutions.

The Industry of the People is an important element of the state politically. So are their Recreations, Tastes, Opinions, Literature, and Science. However much the government abstains from control in these matters, its operations in its proper sphere are influenced by every one of them. An agricultural community gives a peculiar character to the entire action of its government. A community largely occupied in foreign trade involves the government in relations with foreign countries.

14. The good or ill working of the Political system leads to a variety of situations, requiring the consideration of the political reasoner.

When the government fails to accomplish its main functions —defence, protection, justice, &c.—it receives the designations, 'bad government,' 'mis-government.' Its badness may consist in partiality to individuals, which is injustice; in not adhering to its own published regulations; in the capricious introduction of changes; in preying upon the community by exactions, or by affronts.

When the government is excessive in its restraints on individual movements, it is called *despotical*, *tyrannical*, *oppressive*; and the re-action or revolt is Political *Liberty*. When it meddles with what might be left to private management, it is said to *over-govern*; the euphuistic phrase is a *paternal* government.

The emphatic expression *Social Order* means, in the first place, that the government, whether good or bad, is obeyed; the opposite state is *Anarchy*, *Revolt*.

Order is also contrasted with *Progress*, *Improvement*, or *Civilization*. Those things that maintain the existing structure in its integrity are said to minister to Order; while the agencies that raise the society to a higher pitch of improvement, are said to minister to Progress. In point of fact, the opposition between the two is very slight; what is good for one is, with very trifling allowances, good for the other (Mill's Representative Government, chap. II).

THEORETICAL POLITICS.

15. The Laws, Principles, or Propositions, of political society, together with the Methods of Investigation, constitute Theoretical Politics.

The foregoing head, including the Analysis of the Social Structure, the meaning of State of Society, the Notions of Politics—is preparatory to the enunciation of the Laws of Society, so far as known. These Laws are best discussed in the theoretical form; they may afterwards be changed into the practical or preceptive form, that is, into maxims of the Political Art.

16. The Laws of Society may be either Laws of Coexistence, or Laws of Succession, of the different parts of the Social Structure. In both cases, they are laws of Cause and Effect.

The complex structure of Political Society involves many relationships of Co-existence and of non-coexistence. Some arrangements always carry with them some other arrangements; some things are repugnant to other things. The remark was made by Volney that the 'plains are the seat of indolence and slavery, the mountains of energy and liberty.' But whatever co-existences and repugnances can be predicated generally are dependent on causation.

Again, we may take any one part of the social structure as a cause, and lay down the laws of its effects; as when we describe the consequences arising in a given state of society, from an absolute monarchy or from a state church.

We may even take up an entire state of society, with all its mutual actions, and endeavour to trace its future destiny. This is the large problem of the Philosophy of History.

But for devices of simplification, such problems would be wholly unworkable; the complication of elements could not be embraced by the human mind. We should need to fasten upon some single agency, either comprehending, or outweighing the others, whose solitary operation will give the key to the entire problem. The state of opinion and enlightenment of a community is an example of those over-mastering circumstances.

Human Character as a Political Element.

17. As the subject-matter of Political Science is human

beings, the characteristics of humanity must enter as a primary element.

If all human beings were alike, either wholly or in those points concerned in political action, the construction of a political society, whether easy or not, would be but one problem. But there are wide differences as regards peculiarities of character essential to the working of the political scheme. The differences between an American Indian, a Hindoo, a Chinaman, a Russian, an Englishman, an Irishman, an Italian, taken on the average, are such as to affect seriously the structure and the workings of political institutions. Given a certain Form of Government, or a certain constitution of Landed Property, the tendencies would alter greatly under these various types of character.

The theory of Society consists in stating how human beings will act under a given social arrangement; it is, therefore, essentially a special application of the laws of mind and character. Hence a thorough knowledge of whatever Psychology can teach would be a preparation for this study.

Yet, all parts of human nature are not equally concerned in political action; the ethical qualities of Honesty, Industry, Steadiness of Purpose, are more vital than the Artistic sensibilities.

Moreover, Politics is concerned only with the characteristics that appear in collective bodies. The politician leaves out of account all those individualities that are merged when men act together in a body; that is, the qualities occuring merely in scattered individuals and in minorities. Whence, national character is a much simpler phenomenon than individual character; as the flow of a river in mass is a simpler physical problem than the molecular adjustments of the liquid state.

18. A Political Ethology would be a modified science of character, consisting (1) of a selection of the qualities that appear in national character, and (2) of the laws of their operation.

(1) Following the divisions and subdivisions of character, as formerly sketched (p. 288), we should have to bring out into prominence all that arise in human beings when working collectively.

Thus, to commence with ACTION, in the form of Spontaneous Energy. Prior to an account of the various motives that induce men to activity, there is a notable peculiarity of cha-

racter in the degree of the energetic disposition itself. Now this shows itself, as high or as low, in whole nations, and is of importance as respects both the Form of Government and many other political arrangements. The inhabitants of temperate climates are superior in natural energy, irrespective of all modes of stimulation. to the dwellers either in the tropics or in the arctic circles. The English and Anglo-American peoples are probably at the top of the scale.

Now this attribute has numerous social bearings. It favours private industry and the accumulation of wealth, an effect leading to many other effects. It is both directly and indirectly hostile to monarchical or despotical rule, and is, therefore, the parent and the guardian of liberty.

In like manner, we might survey in detail the FEELINGS, Sensibilities, or Emotions of the mind, and mark those that have social significance, and those that appear in men collectively. Thus, the Tender Sentiments, or the Sociability of the Mind, when strong, draw human beings together in society, and favour the cohesion of states as well as of families. Again, the strength and the mode of the Sentiment of Power may be a collective peculiarity, with national consequences. The conjunction of tender feeling, as patriotism within our own nation, with the love of domination beyond, is a peculiarity often repeated.

The INTELLECTUAL qualities that stand out in national prominence are too numerous to be touched upon. It was an intellectually minded people, the Greeks, that began all the civilization flowing from science or philosophy. There is a certain depth of ignorance and incapacity that renders the higher modes of Political society impossible. A signal failure in either of the intellectual virtues—prudence and sympathy, is incompatible with political union.

(2) The next part of Political Ethology is an account of the tendencies of these various characteristics, and of the means whereby they themselves are modified. The general science of character embraces this investigation on the wide scale, and the present department is a special application of the principles.

Propositions of Theoretical Politics.

19. The Political Structure, or Organism, being defined, the Laws of Theoretical Politics are the laws of Cause and Effect, traceable in the working of the several Institutions.

What are the consequences of Absolute Monarchy, or of

Democracy; of Castes; of Entails; of Free Trade; of Poor Laws; of Indissoluble Marriage; of State Churches? These are a few of the enquiries of Political Science; they are strictly enquiries of Cause and Effect. Given any of these institutions as causes, the effects may be sought. Again, given certain effects, as the repression of agrarian crimes, the impartial administration of justice, the encouragement of trade,—we may seek for causes. This is really the same problem in a different form. To all intents and purposes, the one enquiry is—Given a cause, required the effect?

It is not uncommon for political philosophers to entertain such problems, as What are the effects of Monarchy, Aristocracy, Democracy, in general; what are the effects of Slavery in general, that is, under all circumstances, under every possible variety of human character. Now, with such strongly-acting causes as Absolute Monarchy, there may be assigned certain universal tendencies so decided as to be seldom wholly defeated. There are points in common to the despotism of a single person in all countries and times. The possession of power, whether on the great scale or on the small, operates with remarkable uniformity. This is a psychological tendency whose free course is best seen in politics; where, by the necessities of the case, individuals have to be entrusted with power in a large amount. The same consideration renders the workings of slavery uniform to a high degree.

20. The Propositions of Political Science range between two extremes; on the one extreme are propositions affirming universal tendency, and, on the other, propositions affirming specific effects in limited cases.

(1) The propositions affirming a universal tendency are exemplified above. Similar propositions may be found respecting every institution of human society. In many institutions, however, the tendencies are difficult to find out, and are so liable to be defeated by other causes, that their enunciation has scarcely any value. For example, the operation of guilds, or privileged corporations, admits of no definite statement with reference to all possible circumstances. The division of land into large or small properties may have opposite effects in different social states.

Nevertheless, the attempt should be made to generalize the tendencies both of the Forms of Government, in their detailed varieties, and of all the leading Institutions growing out of legislative action. It is equally indispensable to estimate the

precise worth of this class of propositions, to be aware of their infirmities, and of the cautions needed in applying them. There are prevailing tendencies of every important Institution —of the Succession of Land, of Direct or Indirect Taxation, of Religious Endowments, and the rest. The affirmations respecting these are only *probable;* they afford a certain presumption of what will actually happen in individual cases. The special departments—Political Economy and Jurisprudence—share the burden of these difficult problems.

(2) Propositions confined in their range to limited circumstances, to a narrow field of observation, may be so qualified as to state the causation with almost perfect exactness. Thus if we confine our views to communities in similar climates, of the same race, of nearly the same advancement in general intelligence, we can formulate with comparative precision the tendencies of a given institution, whether the Form of Government, or any of the other leading social elements. These Limited or Partial Theories are the really valuable parts of Political Science; they afford the guidance in the art or practice of Politics.

With a view to these propositions, there must be a division and subdivisions of communities into classes. An example of such a classification is given by Sir G. C. Lewis, as follows:—

'One large classification of communities for the purpose of a common predication is—1, those communities which are in a wild and unsettled state, such as the African and Indian savages, the Bedouin Arabs, the Nomad Tartars; 2, those Oriental communities which live under a regular political government, but whose social state is nevertheless fixed and unprogressive, such as the Turks, the Persians, the Hindus, the Chinese, the Japanese; 3, Christian communities partaking of the modern European civilization.'

Setting aside the first class, as affording too limited a field for political data, Sir G. C. Lewis institutes a comparison and contrast between Oriental and European communities, showing the numerous important peculiarities that may be affirmed of each of the two classes as a whole. The following are some leading points of the contrast.

ORIENTAL.	EUROPEAN.
Government.	
Despotical	Free
By Delegation	Direct from the centre
International Law.	
Rude	Intricate, forming a balance of power

Laws—Civil and Religious codes.	
Interwoven	Distinct
Marriage.	
Polygamy	Monogamy
Women.	
Secluded	At large
Status of the Labourer.	
Slavery	Civil Freedom
Punishments.	
Cruel	Mild
Dress.	
Loose	Closely fitting
Alphabet.	
Intricate	Simple
Form of Literature.	
Poetry and mystical prose	Argumentative prose.

Numerous propositions of Cause and Effect could be laid down respecting these peculiarities, connecting them with one another, and with the Climate and Physical Situation, the Physical and Mental Constitution, and the Historical Antecedents of the oriental races.

Methods of Theoretical Politics.

21. As in all other sciences, there must be Observation of Facts.

In Political Observation, there are special peculiarities amenable to logical canons. The education of a political observer is scarcely in any degree, as in the physical sciences, an education of the senses; it consists mainly of intellectual habits.

22. The Facts of Politics coincide with authentic History or Narrative.

The individual occurrences that, when generalized, make up political principles, have to be correctly recorded, with all the circumstances essential to the link of causation. The sequence of events in a revolution must be stated exactly as they occurred, and in sufficient fulness to give the conditions of canse and effect.

The rules of historical evidence are a branch of Inductive Logic, and as such they are given elsewhere (Appendix, I). They have in view principally the number and the nature of the testimonies needed to establish the truth of a past event.

A farther exercise of discrimination is requisite in the political historian, namely, to include all the circumstances entering into the chain of causes, and to separate accompaniments that have only a poetic interest. To do this, the historian must be himself a political philosopher; he must know that the dazzling glitter of spears in the sun has nothing to do with the fighting strength of an army, that the stature, complexion, voice, or dress of Charles I. had no bearing upon his quarrel with his parliament. In short, as regards the relevance of facts and circumstances, the narrator must understand what it is to trace cause and effect in history. 'In order to frame a coherent narrative, *some* theory of causation is necessary' (Lewis).

23. In Politics was first developed the reducing of observations to the form called Statistics; definable as the observation, registration, and arrangement of such facts as can be given in *numbers*.

The cultivation of statistics was first owing to the impetus given to political economy by the French economists; it being possible to state in numbers the most material facts regarding trade, currency, taxation, production, population, &c. The subject now comprises matters relating to all branches of political observation; Population, Births, Marriages, Deaths, Occupations, Diseases, Crimes, Pauperism, Education.

Statistics gives an entirely new precision both to Theoretical or Speculative Politics, and to the operations of government. The increase or diminution of pauperism or of crime, in a large country, could be judged only in the vaguest manner without statistical returns from the officials concerned. The government would be at the mercy of accidental displays, and of circumstances where the impressions are exaggerated. A bread riot in a particular locality, an outrage of appalling accompaniments, would distort the judgment of the nation, as to the general state of destitution or of crime.

24. The causes of erroneous observation in Politics, are partly common to the sciences generally, and partly special to the political science.

Indolence and inattention, the love of the marvellous, æsthetic likings and dislikings, the support of a favourite theory, are operative in politics as elsewhere. The more special sources of bias in the political department are admiration of individual actors, party feeling, and, where practice is

concerned, direct personal interest. As a matter of course, these corrupting motives extend their influence to the generalizing no less than to the observing of facts.

Politics deals with human beings, whose springs of action are in the mind; while observation relates only to outward appearances, from which the mental states are obtained by inference. The right performance of this process of inference is an operation based on Psychology, and guided by the rules of Inductive Logic. That Charles I. was executed is a fact; the motives of Cromwell and the Puritans in executing him are a matter of difficult inference; requiring us to apply laws of human nature (veracity, bias, &c.), to what the actors said and did in connexion with the fact. The secrecy of motives is the characteristic of many ethical maxims.

Experiment in Politics.

25. Experiment, in the strict scientific meaning, is usually regarded as inadmissible in Politics. The substitutes are (1) the sudden introduction of extraordinary influences, and (2) the practical operations of government.

It is not possible to submit a society to the process employed in studying a metal, or in detecting the laws of Heat or Magnetism. A political community cannot be manipulated with a view to excluding artificially this or that agency, isolating it from all but known circumstances.

(1) Some of the advantages of experiment are derivable through the introduction of a new and extraordinary influence into the society—such as a famine, a commercial crisis, an insurrection, an epidemic, an invasion, a new invention, as the steam engine, a religious revolution. The Irish potato famine of 1845, is adduced by Lewis as a case in point. The influence of this terrible calamity laid bare the evils in the state of the Irish poor, and disclosed the secret springs in the social economy of the people, as effectually as could have been done by an artificial experiment contrived for that purpose.

(2) It is the very nature of government, especially an improving government, to be trying experiments. Every new law is an experiment. There being an object to be achieved by the law, the public is supposed to be interested in watching the effects of the measure. A Police is organized, and the effects upon crime observed. A Poor Law is introduced, and the consequences traced. So every great innovation is a new agent in society, which is followed by definite effects. The

experiments are not always free from ambiguity; there may be concurring agencies either defeating or exaggerating the results; hence a demand for the precautions of the various Inductive Methods.

Causation in Politics.

26. In Political Causation, the predominating fact is Collocation; there is seldom, yet occasionally, an appeal to Conservation.

A political sequence is always immersed in a host of arrangements, positive or negative; and although impelling forces must always be present, the result is dependent in a pre-eminent degree upon the direction given to these forces. Thus, a political rising depends less upon the greatness of an impelling force, than upon the direction given to forces always present. The demand for thirty shillings of ship money from John Hampden was the turning point of the English Revolution.

Yet in dealing with human nature, whether as individuals or political masses, any omission to allow for the principle of Conservation, in the form of Limitation of Human Energy, will lead to mistakes. Thus, a politician that would expect an Art-loving people like the Italians, Germans, or French, to take on the energy of the English in business and in politics, without becoming less artistic, would be guilty of overlooking the law of Limitation.

27. In Political Causation, it is especially necessary to keep in view the entire aggregate of conditions, positive and negative, entering into the cause.

When Luther preached against Indulgences, and when Hampden refused to pay ship money, these were merely a single condition out of a large assemblage concerned in bringing about the great events that ensued. Hence, the historian considers it requisite to describe the whole of the surroundings in the state of society at the time, but for which the consequences would not have arisen.

To seek the cause of a political event in a single circumstance is a perversion of the political problem. The most enlightened reasoners and historians are accustomed to state the case as an enquiry into the *causes* of a phenomenon. The phrase is not strictly correct; the entire aggregate of antecedents is properly the *cause;* but as bringing forward the

idea of *plurality* of circumstances, conditions, or collocations, the mistake is on the right side. The causation of the French Revolution was a vast aggregate of prior arrangements in the state of the French nation, together with numerous circumstances in the world at large.

The Method of Agreement in Politics.

28. The Method of Agreement enters into political investigation, but not without shortcomings.

Like every other inductive enquirer, the political reasoner first collects his facts; then compares them with a view to attaining laws of concomitance, which he farther verifies by Agreement, as a method of Elimination.

This has always seemed the obvious course. When Aristotle enquires into the effects of Despotical or of Democratical government, he collects examples of each, and looks out for the attendent peculiarities. By an inductive determination, founded on Agreement, we are accustomed to connect different forms of government with lower or with higher stages of civilization.

The first peculiarity of the inductive problem of society, as affecting the sufficiency of the Method of Agreement, is the mere *number* of concomitant circumstances in a state of society. The cause A, say Despotism, works in conjunction with such a large variety of other circumstances,—climate, race, history, institutions in detail—B C D E F, &c.,—that we can hardly find in the whole area of our experience a sufficiently diversified series of instances to eliminate them all, and find A followed in every instance by *a*.

Worse than the mere number of accompaniments is *plurality of causes* with *intermixture of effects*. Whatever results might really flow from Despotism—whether discontent and insurrections, or the repression of men's energies and the arrest of prosperity and progress—could flow from other social agencies; the effect *a*, an actual effect of A, might also be an effect of C, F, H. This would not prevent *a* from being always present with A; it would rather in some instances make it superabundantly present; yet, as proving too much, it would be fatal to the evidence. An apparently more paralyzing instance would be, when the effect *a*, properly belonging to A, is neutralised by some accompanying agent D; one of the commonest of all occurrences in politics. Hardly any effect of absolute monarchy is better substantiated than the discouragement of intellectual

activity generally; yet this did not follow at once on the imperial despotism of the Roman Empire; the prior impetus acquired under free institutions was for a long time unspent. So, a law designed to produce a certain effect, may really be acting as intended; but the effect may be frustrated by evasions, or by passive resistance to its enactments. Restrictions on trade are adverse to commercial prosperity; yet the effect may happen to be counteracted by other circumstances. The United States of America, in the abundance of land to be occupied, can prosper under many arrangements that would be ruinous to Great Britain.

The other Experimental Methods.

29. The Method of Difference may be exemplified in Political Cause and Effect.

The introduction or withdrawal of a single agent, followed at once by a definite change in other respects, is our most cogent, as well as our shortest proof of causation. In the complications of Political Society, we cannot always be sure that only the one innovating circumstance is present; so many unseen operations being always at work. This source of ambiguity is practically overcome when an agent *suddenly* introduced, is almost *instantaneously* followed by some other change; as when the announcement of a diplomatic rupture between two nations is followed the same day with a derangement of the money market.

According as the supposed change is more gradual in its introduction, and the consequences slower in their development, the instance is less and less a decisive example of difference. The deterioration of value is saved only when we are sure that every other thing has remained the same. A new religion introduced into a nation, remarkably stationary in its other institutions, would be held as the cause of all the subsequent changes.

30. Agreement in Absence may be advantageously resorted to in Politics.

We compare the cases of the presence of Poor Laws, of Commercial Restrictions, of a Standing Army, of Local Self-Government,—with the cases of the absence of these institutions; and if any circumstances uniformly present in the one are uniformly absent in the other, the force of proof is greatly augmented.

30. Concomitant Variations is employed in tracing political causation.

There is a marked concomitance, in the History of England, between the growth of Free Institutions, and the progress of *the nation*, both materially and intellectually. This may be compared with the inverse instances of Greece and Rome, where, by a gradual process, the extinction of liberty was ultimately followed by intellectual and social decay. Even all these instances, in the complications of Politics, may not be final; yet they afford a very high presumption of cause and effect

The Deductive Method.

31. The Deductive Method, in conjunction with the Inductive or Experimental Methods, must be regarded as the mainstay of political investigation.

Neither the Deductive Method alone, nor the Inductive Methods alone, can be trusted in the complications of the social science. Their mutual consilience or confirmation, is requisite in order yield trustworthy conclusions.

Pure Deduction appears to most advantage in following out the tendencies of separate agents. This is the motive for subdividing the Social Science into branches, as Political Economy, &c. The tendency of the single motive of the desire of wealth can be studied apart from other tendencies.

An essential part of political deduction consists in tracing the wide operation of the Sentiment of Power, in the various degrees of its development among human beings, and under all circumstances. The deduction should comprise a wider area than mere political situations.

The Sociability of mankind, their Sympathies, the grades of Intelligence, have consequences traceable by a purely deductive operation.

We might even venture a certain way in the second deductive process—Calculation or computation of concurring agencies; as Wealth, Power, Sociability, Sympathy, with Habits, Customs, &c. Here, however, we become aware of the helplessness of the deductive method by itself. Having no correct quantitative estimate of the separate agents, our attempt to combine them in a quantitative sum, is entirely hopeless. The errors of calculation may be so wide as radically to vitiate the conclusions.

It is the third step of Deduction—Verification—that gives

the method all its weight, by joining it with Inductions. In point of fact, politicians in applying the cónjoint methods usually have an inductive or empirical generality presented in the first instance; which induction they compare with the deduced tendencies of the agents concerned. Thus the working of despotism is first given as an empirical generalization from history; we then compare these alleged results with the deductive consequences of the love of power, and all other human motives, both of the ruler and the ruled, entering into the situation. Such maxims as the following require, for their verification, the consilience of induction and deduction.—'The possessors of supreme power, whether One, Few, or Many, have no need of the arms of reason; they can make *will* prevail.' 'The governments most distinguished for sustained vigour and ability have generally been aristocracies.' The deductive reasons in favour of this last position are founded on the consequences of devoting a small number of men exclusively to public business.

Thus, the usual course of the Deductive Method is to lay hold of a number of *empiricisms*, derived from history and political experience, and to subject them to the test of deduction, thereby converting them into *derivative laws*. Considered as inductive generalities, everything should be done for them that can be done by strict compliance with the Inductive Methods; after which they are to come into comparison with the deductive results of the tendencies concerned.

Among Empiricisms demanding to be confronted with deductive conclusions, we may instance the following—'modern civilization tends to collective mediocrity,' (J. S. Mill); 'unity in religion is unfavourable to civil interests' (G. C. Lewis); 'there is no necessary connexion between hereditary royalty and hereditary nobility' (*ib*); 'the human race is on the whole progressive'; 'there is a constant relation between the state of society and the state of intellectual speculation'—(Comte).

Deductive confirmation is especially needed in assigning the causes of some one historical event. Unless there happen to be other events closely analogous, our inductive basis is of the slenderest kind; succession may be taken for causation without any check. Thus, the account of the rise of free institutions, in modern Europe, must be far more deductive than inductive.

The introduction of Christianity into Europe co-existed with so many other changes, that its consequences cannot easily be

eliminated. Our only means of varying the instances is to take the separate nations apart; but in none of them was this one cause introduced singly. Hence any inference as to the political and other results of Christianity would want much deductive confirmation; and we find that this method is largely appealed to. The tendencies of the Christian religion are laid out deductively, and the attempt is made to show their coincidence with the facts. To be properly checked, a similar deduction should be made of all other tendencies—as Greek and Roman influences, and the mental endowments of the European races; which subtracted from the total would give a case of the Method of Residues.

In the foregoing brief allusion to the Deductive Method is included a reference both to Empirical and to Derivative Laws. The subject of Politics furnishes pertinent examples of the *limitation* of Empirical Laws, and in a less degree of Derivative Laws, *to adjacent cases.* There is safety in extending an empirical law only to the same territory, the same time, and similar circumstances. When a ten pound suffrage had subsisted in Britain for thirty years, with good effects, it was a small matter to risk the extension to a seven pound or a six pound franchise, on the mere faith of the empirical coincidence; whereas, the sudden transition to universal suffrage, could not be relied on from the same empiricism. The consequences of such a step, if computable at all, could be computed only by the aid of *deductive* reasoning—by the establishment of a derivative law. A well-informed, sagacious, and unbiassed reasoner, might be trusted to predict, within certain limits of error, the probable issue of such an extension of the franchise; but only by a superior handling of the deductive method.

The Method of Residues being properly a Deductive Method, is occasionally valuable. It takes the problem on a varied aspect; as in the case of Christianity already referred to.

In applying the methods of Agreement and of Difference, to single out a cause, our prior knowledge of the general adequacy of the cause, prepares us to receive the inductive evidence, without the misgivings that we must feel when we know nothing on this head.

Hypotheses in Politics.

32. In Politics, we are seldom under the necessity of assuming an unknown agency; the known forces of human nature are the sufficing causes. Our assumptions refer to

the presence, and the amount, of the supposed agent; and these may be proved by their exactly tallying with the facts.

Assumptions are perpetually made regarding the conduct of human beings under all circumstances. The passions of Power, Pride, Fear, the Self-interest of men, their Sympathies, are all real or genuine causes. There may be doubts which of them produced a certain line of conduct; and we may apply the logical conditions of hypotheses to solve the doubt. If any one's actions tally precisely with the consequences of Love of Power, we receive this coincidence as so far a proof of the hypothesis. But the proof is completed only by showing that the action does not tally with any other motive; a thing that we cannot always be certain of. The execution of Charles I. might have resulted from the fears of the Puritans, from their revenge, from their ideas of justice, from their interpretation of the designs of providence. A proof from hypothesis would have to show that the act coincided fully with the tendencies of *only one* of all the supposable motives.

Simplification of the Political Problem.

33. There are various modes of reducing the complications of Politics. Several of these have already been glanced at.

(1) By studying Institutions separately, due regard being had to their mutual action. This is that primary Analysis of Society which is the groundwork of scientific method throughout. There may be difficulty in making the isolation, and yet allowing for mutual influence; but any other method is hopeless.

(2) In modern political theory, much stress is laid upon the distinction between Order and Progress; and we are recommended to study separately the influences tending to Order or Stability, and the influences tending to Progress or Improvement. The advantage of this separation is chiefly to divide the field of study, for the ease of the understanding. It has been shown by Mr. J. S. Mill (Representative Government, Chap. II.) that the two interests cannot be absolutely separated; there can neither be Progress without Stability, nor Stability without Progress; yet the problem of Society is greatly simplified by first studying each by itself, and then paying attention to their reciprocal action.

Mr. Mill has traced, by the combined Inductive and Deductive Methods, the conditions of Stability in any society, and has referred them to the following heads:—(1) An education of the citizens calculated to impart a *self-restraining discipline*; (2) a *feeling* of allegiance or loyalty to something; (3) an element of *cohesion* among the members of the same state. It is apparent that all these causes, while arising from the inductive comparison of societies, may also be fairly deduced from general principles of the human mind; the consilience of the two results being essential to the proof.

(3) In the variation of political circumstances, the propositions of society would be numerous beyond calculation, but for the eminently scientific device of embodying a limited number in their exact circumstances and conditions, so that they may be varied at pleasure. It may be a question whether certain public works should be overtaken by the central government or by the local government; as bridges, roads, prisons, &c. Now the decision of this question in any one case, if accompanied with all the circumstantials that govern the decision, is the decision for innumerable other cases, even although differing considerably from one another. Thus, if the central government undertakes the work, avowedly and solely because the locality cannot bear the expense, this decides also the opposite case, where the locality *can* bear the expense.

It is thus that legal judgments, if accompanied with a full statement of reasons, may apply to a wide range of differing cases. And so also with all reasoned conclusions in politics. The very same proposition that declares the consequences of a despotism in given circumstances, implies the variation of the consequences in degree, as the despotism varies in degree; and the reversal of the consequences by the substitution of freedom. All such adaptations and principles are to be held as of the nature of deductions, for which inductive verification is desirable according to the extent of departure from the case embodied.

(4) Attention has already been called to the circumstance that Politics deals with men collectively, and not individually. In the view of the politician, a million of human beings is a less complicated thing than a single individual. The large scale of the operation reduces its complications. The maxims for governing a nation (in a certain rude way) are simpler than the maxims for managing single persons, if we have to consider all the minute peculiarities of each. The Foreign Minister, who has to transact business with one individual,

may have his ingenuity and patience more severely taxed than the Home Minister, who deals with the mass of a nation. The limits of the proposition are contained in the reasons of it (as just remarked); if the mass of the community breaks up into individualities, by social discord, there is an end to the facility arising from collectiveness of action.

(5) Not the least important simplification of the Political Problem, whether for theory or for practice, is the Limitation of the Province of Government—the transferring of business from Public to Private management. The tendency of all societies has been to Over-government; and the relaxation of this is one of the favourable symptoms of existing societies. The proper province of government is a question to be solved according to the circumstances of the time. A state religion may be suitable under one state of things and unsuitable in another; so great are the advantages of disburdening the civil ruler of such a charge that a case must always be made for retaining it.

Fallacious Methods in Politics.

34. These are for the most part implicated in the statement of the sound methods.

(1) The exclusive employment of the *Experimental* Methods is shown to be insufficient in the complications of Politics. How much more so is mere Agreement without the studied variation of circumstances demanded by the method; and yet such is the usual procedure of untutored minds. Thus, any institution whatever is pronounced beneficial, because the country has prospered under it. This is the grossest form of empiricism. The careful employment of the Experimental Methods would avoid such errors; but would still be inadequate.

(2) A purely *Deductive* Politics is equally at fault. Even starting from the best Psychology, and the best Ethology elaborated with an express eye to Politics, we should never be able to infer tendencies with perfect precision, still less to compute the sum of a plurality of tendencies. With the highest skill in psychology, with the best possible appreciation of the average development of the great leading attributes of the mind, in a given race of men, and with the closest attention to physical and other circumstances,—we should still break down in the attempt to say, how a community formed from such a race, could prosper under either a despotic or a democratic government, with or without a religious belief.

Allusion has been made to the error of seeking a political cause in a single circumstance, instead of an aggregate situation, or group of circumstances.

(3). Sir G. C. Lewis has fully illustrated the assumption of false and fictitious causes in Politics. Such are mythical or legendary causes; fictions of law; and the supposed social contract suggested by Grotius, and formally argued by Hobbes.

PRACTICAL POLITICS.

35. In every Practical Science, we must begin by setting forth the End. In Politics, as in Ethics, this may be variously viewed.

In most practical sciences, there is no dispute as to the end. In Ethics, and in Politics, the case is different. Even, when parties agree to call the end 'human happiness,' they differ in the meaning attached to it.

In antiquity, the Athenian and the Spartan Ideals of Society were totally different; so much so that, on the basis of the same Theoretical Principles of Society, the rules of Practice would be distinct. The end in the Roman Republic was the power and glorification of the State. A leading design of the Spanish rule of America was the conversion of the nations to Catholicism.

According to some, the end of the political machine is good government, or the best mode of carrying out the primary objects of Defence, Security, &c., on whose account society exists. If a despotism accomplishes this best, a despotism is the best government; if not, not.

Others, as Mr. Mill, maintain that the cultivating of the energies of the people is an end independently valuable. When this is coupled with the farther assertion, that by such means alone can a high standard of government be maintained, then both parties agree as to the end, but differ as to the means. It is, however, possible to maintain that a worse government by the people themselves, is preferable to a better that excludes them.

Another way of expressing the same antithesis of ends is to contrast passive enjoyment with free action. It may be held, on the one side, that what gives the greatest amount of sentient pleasure with the least pain, is the highest ideal of society; and, on the other, that what allows the greatest scope to liberty and individuality, with or without mere sentient enjoyment, is absolutely the best.

These different modes of conceiving the ends of society have a great influence on actual practice. The 'paternal governments' will not conform to the plan of leaving to the individual the utmost liberty compatible with the liberty of others.

36. The Political end being stated, the principles of Theoretical Politics are all convertible into maxims of Practice.

The principles of Causation in society, when stated as laws of the order or succession of events, are theoretical principles; when stated as rules for effecting a given object, are practical principles or maxims. Discussing theoretically the workings of Democracy, we trace certain tendencies of the predominance of the numerical majority, and the tendencies of certain political arrangements to counteract these; whereupon, having in view the end of allowing no class unlimited ascendency, we lay down as a maxim or rule the providing of such checks.

Theoretical politics enounces the proposition that certainty of punishment is more deterring than severity; practical politics converts this into the precept,—Make punishments certain rather than severe.

The requisites of Stability above laid down are convertible into maxims for attaining stability. So with the theoretical conditions of Progress.

Although Practical Politics is thus Theoretical Politics over again, with the addition of well defined ends, there are great advantages in laying out the subject in both forms, we being aware that the substance is the same. The theoretical form is the one most convenient for investigation; while the repetition of the principles in the preceptive dress, if done so as not to confuse the mind, is both suggestive and corrective. Moreover, it is only by the separate treatment of the two departments, that we do full justice to the special point raised in the practical department—the political end. The full handling of the various modes of viewing the end would justify a long preliminary chapter of Practical Politics.

It has been well pointed out by Sir G. C. Lewis that the propositions of politics are ordinarily cast at random, sometimes in the theoretical, sometimes in the practical mould. 'The more haste, the worse speed' is theoretical; '*festina lente*,' is practical.

Much of Theoretical Politics may be unavailing for practice, at least the limited practice of a given country and time. The

theory of Politics, in its most imposing pretensions, comprehends the Philosophy of Universal History, much of which is of limited practical application. Hence the practical branch is content with selecting a portion of what has been elaborated in theory.

Again, the practical mode of selection has the farther peculiarity of altering the arrangement or grouping of the political dicta. In the theoretical investigation, the *general tendencies* of different institutions are described in a methodical array—Forms of Government, War organization, Police, Justice, &c. With a view to a practical end, we borrow from many different parts of the theoretical exposition, the *specific links of cause and effect* conjoined in a peculiar structure, as for example, the Poor Law of a given country. This is the prevailing form of all practical departments with reference to the allied theoretical sciences.

Many of the greatest social devices have originated exclusively in the hands of men of practice, and have been stated first in the practical shape; being afterwards enounced in theoretical propositions. Such are the English Constitution, the union of Local Management with Central control and Inspection, the system of fastening Responsibility upon the real authors of political acts. Mr. Mill regards as one of the most valuable securities yet devised for good government, the device that grew up in the East India Company's rule, namely, to associate the chief administrator with a Council to advise, but not to compel; thus leaving the responsibility upon a definite individual.

CHAPTER IX.

LOGIC OF MEDICINE.

1. The scope of the Practical Science of Medicine is given by the Definition of the correlative couple—Health and Disease.

The phenomenon, expressed by Health on one side and Disease on the obverse, is indefinable; it is an ultimate fact of human experience like Life itself, of which it is a unique mode or manifestation. The attempt to convey a notion of Disease to a person that had never seen or experienced any examples

of disease, would entirely fail. To call it 'a perverted Life Process' is to give an analogical phrase, but as the phenomenon is unique, analogy gives no assistance.

Thus, although Disease is a highly complex fact, yet so novel are its manifestations, that we must define it by the methods adopted for our simplest experiences, as resistance, motion, colour, line, angle. We must refer to a number of examples in the concrete, and generalize these into a comprehensive statement, which the examples make intelligible. After we become acquainted with a certain number of diseases, the others can be understood by description alone.

It is barely possible that without actual experience of Inflammation, one might form a constructive notion of it from its technical characters—objective and subjective. The objective characters—redness, swelling, heat—might be conceived; the pain also, if otherwise known to us, could be called to view, and united with the other symptoms; and the mind might laboriously fuse the whole together. This is only not impossible. But the greatest powers of description in the expositor, combined with the highest constructive faculty in the learner, would break down in the endeavour to realize Fever. The subjective experience, being one unknown to a person that had never been out of health, would be unintelligible in the reference.

A few experiences of Disease give a meaning to the correlative notion—Health; whence we can define disease *negatively*, by the infringement of Health. The positive definition, would be the result of the comparison of all the modes of derangement, the generalization of diseases; but writers usually remain content at the outset with the negative statement; in other words, they define Health, by assuming the knowledge of a few specimens of disease. Health, in its most complete acceptation up to this time is the absence of all the 1146 diseases put down in the 'Nomenclature of Disease.'

The science of Medicine is an adequate description of all these forms of derangement, or departure from Health, with a view to suggest means for averting or removing them. This practical end implies an extensive knowledge of *causation* with reference to Disease.

As regards the large number of Diseases, the complicacy of their characteristics, and the existence of generic and specific agreements and differences among them, impart to the science of Medicine a certain community with the Natural History, or classificatory sciences—as Mineralogy, Botany and Zoology.

The analogy to the two last is still closer through the circumstance of evolution, or the succession of stages, in most diseases.

Sciences preparatory to Medicine.

2. Disease being a state of the Human system, the science of medicine rests immediately on the part of Biology, called Human Anatomy and Physiology.

All animals, and even plants, are liable to abnormal action, or disease. The consideration of the subject, however, reaches the highest development in connection with human beings. Animals share in many of the human diseases, and have some special to themselves.

When we name Biology, we may be supposed to exhaust the sciences preparatory to medicine. Strictly speaking this is true; inasmuch as all other knowledge applicable to disease is applicable through biological science. Yet it is well to advert emphatically to the inorganic sciences—Natural Philosophy and Chemistry—which, in their present improved condition, yield many suggestions bearing at once on the medical art. Physics, in both its divisions—molar and molecular, Chemistry—both Inorganic and Organic, are full of applications to medical biology. The medical man, in order to derive the full benefit of these scienes, needs to study them apart, as well as in their applications in Human Physiology.

Intermediate between Human Physiology and the Practice of Physic, are the exhaustive enquiries into special organs, and special functions; as exemplified in the work of Dr. Parkes on Urine, and in the researches of Dr. Edward Smith, Prof. Haughton, and others, as to Food, Muscular Power, Respiration, and other applications of Physics and Chemistry, with experimental checks and verifications.

Pathological, based on Physiological, Analysis.

3. The Analysis of the Organism for Physiological purposes is likely to prove a basis of Pathological analysis.

It being found that the greater number of Diseases are localized in separate organs or tissues, we are aided, in classing diseases, by a full enumeration of all those independently diseasable parts. Now, Physiology reckons up the separate tissues and organs of the body; and Pathology enquires whether these are all separately subject to disease. The classification of diseases (with the exception of what are

termed general diseases) is made to follow the physiological division of the organs—Brain and Nervous System, Senses, Circulation, Absorbent System, Ductless Glands, Respiratory System, Digestive System, Urinary System, Generative System, Organs of Locomotion, Cellular Tissue, Skin. And inasmuch as most of these systems are complicated groups of organs, for example, the Digestive System, a farther subdivision is made of localities of disease—as Teeth, Gums, Tongue, Salivary Glands, Stomach, Intestines, Liver, &c.

This Anatomical arrangement of the seats of disease would be of little value, did not diseases confine themselves to separate organs, while exercising a secondary influence on adjoining and connected parts, or on the general system. Thus, a disease may accomplish its entire course in the bronchia, the stomach, or the kidney, with no farther injury to the rest of the system than arises from disturbing the balance. When one member of a business establishment is incapacitated, a certain deranging effect is felt throughout the whole; but that effect is a different thing from the incapacity of one making the incapacity of another.

The point for the pathologist to consider, therefore, is what parts and tissues may be saparately diseased. This is to push the *local* analysis of disease to the very utmost. Each of the parts, thus distinguished, must be supposed to have independent vigour or weakness, as measured by the energy of function, and by the resistance to deranging causes.

Even in properly local diseases, however, there must be more or less tendency to affect adjoining or connected organs; and there is thus a *scale* of kindred established between each organ and the rest; disease of the stomach affects the intestines and the liver before the lungs or the kidney.

It must be admitted, however, that the alliance of local connexion is apt to be overborne by the distant alliances established through the two carrying organs—the blood and the nerves.

4. The analysis of physiological Functions is also an analysis of diseased actions.

Every function performed by an organ may be affected in disease; and, in some cases, one function may fall into disorder independent of the others. Thus the liver has a plurality of functions; and disease may consist in changing one, with no more than an indirect result upon the rest. The pathologist needs to avail himself of this analysis likewise.

5. A farther analysis must be made of morbid Products, or substances generated in disease, and unknown in the same localities during health.

This is a department special to morbid Anatomy, or Pathology; and is prosecuted by the assistance of chemical analysis, and microscopical examination. All such products are to be carefully ascertained, classified, and described. After an account of the characters of each, some mention might be made of the diseases wherein they severally manifest themselves. Finally, their causes, known or supposed, might be given. But care is to be taken not to jumble up all these three expositions in one.

There is a close and natural connexion between the account of new morbid deposits and the morbid alterations of the several tissues. The same method needs to be followed with these; each morbidly transformed structure being described with reference to all its appearances and re-actions, ascertained by chemical, microscopical, or other means; the description to be followed as before by mentioning the diseases wherein each occurs, together with any assignable causes of the change.

Enumeration of Diseased Processes—General Pathology.

6. The numerous diseases affecting the various organs of the body, as well as those attacking the whole, consist in the repetition of a small number of *diseased processes.* Such are Inflamation, Congestion, Hæmorrhage, Degeneration, Tumours, &c.

7. The process called 'Fever' is considered as a general disease.

Upwards of twenty forms of diseased process can be enumerated; Fever and Inflammation taking the lead. This is doubtless a great means of simplifying disease, although, in the specific varieties of the different processes, there is a considerable burden of detail. Inflammation is pretty much the same in all organs; being similarly caused, and similarly brought to a termination.

It is proper to give a general and comparative account of every one of these processes, adverting to their modes and varieties, before taking up the special diseases where they enter. Chapters on Fever in general, and on Inflammation in general, are usually provided in advance of the detailed description of diseases.

General Therapeutics.

8. The generalizing of Diseases, through the recurrence of a limited number of diseased process, suggests the generalizing of Remedial agencies.

By way of anticipating the remedies for the special diseases, there is the same propriety in taking a general view of remedial agencies, as in taking a general view of diseased processes; the one being made possible by the other. Very great advantage accrues from studying each remedial agent, not apart from all particulars, which would be absurd, if it were possible, but *in connexion with all particulars.*

For example, that remarkable fact called by the various names—*metastasis*, counter-irritation, derivation, revulsion—should be discussed at the outset on a comparative survey of its characters in all variety of circumstances. This is the only means of gaining a clear and steady grasp of its compass and limitations, or of the causative conditions of its working.

Again, a similar generalized view should be taken of the process called Stimulation, whereby, through a variety of means, nervous action is heightened, with an increase of other dependent functions.

The justification of a General Therapeutics, to assist both in investigating disease, and in treasuring up knowledge for use, is apparent in the great number of diseases that have *no specific.* Take Typhus, for example. The only directions given relate to the employment of the general remedies adapted to the *symptoms* of the disease; cold affusion or cooling drinks for the main fact—excessive heat; stimulants to resist the depression of the powers; purgatives when the bowels are confined; sudorifics, &c.

Although the removal of the *cause* of a disease, with the occasional plying of the opposite, must always be a large part of Therapeutics, it does not make the whole. When the poison of typhus has once entered the blood, the removal of the cause is irrelevant; the effects are already produced, and must be counteracted by new agencies. Hence, we have first, General Causes of Diseases, with Hygiène (which a knowledge of causes may fairly exhaust); secondly, General Therapeutics, as counterworking the derangement actually produced.

General Therapeutics might thus conveniently follow the general account of the Causes of Disease. The two branches are closely connected without being identical. The general causes

are such as—Hereditary Constitution; Atmospheric causes (Miasmata, Cold, Heat, Light, Electricity, moisture); unsuitable Food and Drink; Over-exertion or Excesses; deficient Sleep; insufficient Exercise; Poisons, &c. &c. In the account of these noxious agents is implicated the branch called Hygiène, or warding off diseases by avoiding their causes, under which are indicated, obversely, the causes of that vigour of the organs which we measure by the distance placed between us and disease.

The *Materia Medica* usually contains a Therapeutical classification of Medicines; as Tonics, Exhilarants, Narcotics, Emetics, Purgatives, Sudorifics, Diuretics, &c. The minute detail of properties under each of these classes, occurring in the larger works on Materia Medica, is to a great extent a repetition of general Therapeutics.

Notions of Medicine.—Definition and Classification of Diseases.

9. Of Disease on the whole, there is no definition that is of any value; defining begins with the special appearances of disease.

The very best generalization that can be given of Disease on the whole, is too vague to furnish any useful indications. When we begin to specify morbid appearances, and, under the name of *a* Disease, to group those that are connected in the same outbreak, we are enabled to construct definitions, often short of absolute precision, yet faithful to the great mass of actual instances.

The Notions of disease concern (1) diseased processes, and (2) diseases. The diseased processes include Fever, Inflammation, Congestion, Hæmorrhage, Dropsy, Atrophy, Hypertrophy, Degeneration, Tumours, Parasites, Calculus, Functional weakness, &c. Of these various processes, we may specify as distinguished for their prevalence in common diseases—Fever, Inflammation, Degeneration, and Functional derangement.

Fever.—Fever is a general state entering into many diseases, and now susceptible of being characterized in its generic character. Mainly through the careful observations of Dr. Parkes, a generalization of Fever has been arrived at, such as to conciliate all the appearances. The generalization is expressed by the simple fact—'Elevation of Temperature.' A rise of temperature in the body generally, to the extent of 4° of Fahrenheit, is a state of Fever; while the increase may proceed to 6°, 8°, or even 12° Fahrenheit.

As there is no circumstance characteristic of Fever in general, but this one fact, and its implications or consequences, this is the complete definition of the febrile state. Any explanation or illustration of it should consist in stating a variety of instances showing the elevated temperature.

The following definition is encumbered with statements not belonging to the definition—'A complex morbid state accompanying many diseases as part of their phenomena, more or less constantly and regularly, but variously modified by the specific nature of the diseases which it accompanies. It ESSENTIALLY CONSISTS IN ELEVATION OF TEMPERATURE, *which must arise from an increased tissue change, and have its immediate cause in alteration of the nervous system.*' The first sentence is a pure superfluity. The setting apart of Fever for separate consideration, as a preliminary to the discussion of particular febrile diseases, implies what is therein stated—that fever is a morbid state, and that it accompanies many diseases. All such wordiness should be sedulously avoided in definitions. A different criticism applies to the expressions given in italics —'arising from an increased tissue change,' 'having its immediate cause in alteration of the nervous system.' These are not idle phrases, but describe circumstances of radical importance. Why, then exclude them from the definition? The reason is that the complications of disease require the separate discussion of whatever can be separately discussed with advantage; and, almost everywhere in medicine, it is advantageous to separate the description of the fact, from the enquiry into the causes of the fact. A definition should give whatever is essential to the determining of a fact or phenomenon. It should not assign the causes, nor deduce the consequences of the phenomenon; this is to advance beyond definition to predication, and should be a distinct expository statement.

It is a proper appendage to the definition, to enumerate the ordinary superficial appearances of fever, which constituted its definition before the exact generalization was arrived at, 'hot skin, quick pulse, intense thirst, scanty and high-coloured urine;' at the same time subjecting these symptoms to a critical examination, so as to point out their shortcomings.

The fact of Elevated Temperature being sufficiently shown by an appropriate selection of particular cases, the important predications above alluded to may be taken up. From the Law of Conservation, as applied to the animal economy, there must be an increase of tissue change to support the heat, and

the endeavour should be made to assign this tissue change in its exact circumstances, and numerous outlying effects. The account of fever is not complete without this development. The conclusions of Dr. Parkes, obtained by a large induction, and corroborated deductively by the Law of Conservation, are most valuable. 'The increase of temperature may be (or is frequently) attended with increased elimination; and therefore presumably with increased tissue change.' Again, what seems to contradict the general law of Conservation,—'the products of metamorphosis, as judged by the excreta, may be *diminished* in febrile cases.' The contradiction, however, is only apparent for there is good evidence in such cases, of an undue retention of excreta, which makes one of the bad accompaniments of fever. Careful observations prove that while the actual amount of excreta is small, the tissue-change may still be great.

It is obvious that this topic involves a great amount of detail, ascertainable only by observation, although checked by the general law of definite changes accompanying definite results. The state of every organ, and the alterations in all the excretions — pulmonary, urinary, cutaneous, intestinal, &c.—need to be exactly gathered from the facts, and made a clue to the windings of the special febrile disease.

The second predicate given with the foregoing definition—'the alterations in the nervous system'—also deserves to be illustrated, proved and unfolded, in a separate section.

Other important predications extend the discussion of fever: such are the procuring cause, and the course or evolution, in so far as belonging to fever generally.

The foregoing outline represents the exhaustive account of Fever, as a diseased process. We began with the intention of illustrating *definition* in Medicine; but, it was advisable, once for all, to show the boundary between legitimate definition and predication, which is habitually disregarded in medical subjects to the detriment of the handling, both in a logical point of view, and as regards expository clearness. The filling up of the sketch would be the account of Fever, coming under a previous heading—'Enumeration of Diseased Processes' (§ 6.)

Inflammation. The complication of this state is very considerable; but the method is plain. We must separate the definition from the predications; and, in the definition, we may separate the superficial appearances of the ordinary diagnosis, from the essential fact, or facts of the state.

First as to the definition. The traditional characters of inflam-

mation are the four facts—*redness, swelling, heat, pain*—which are a tolerably close approximation. There might be a convenience in briefly illustrating these points, as a prelude to the improved generalization that can now be afforded.

Even then, however, the only correct course is to adhere in the first instance to a description of the characters, for the purposes of identification; refraining from all remarks bearing on the causes or explanation of the several symptoms. The kind of *redness*, its various hues, the more or less extensive prevalence of the mark,—are the points proper to the elucidation of the property as a defining and diagnostic circumstance; the same rigid plan to be followed with the three remaining symptoms. The triumph of the expositor's art in this effort would be, that no one could ever mistake the inflammatory redness, swelling, or the rest.

The appearances being thus expounded with all the necessary enforcement, it is admissible to consider how far they may be connected, either by implication, or as cause and effect, with one another, or with circumstances still more fundamental. It is then easy to point out that the fact of *congestion* is a very important addition to our knowledge, and, if imparted on the plan now stated, re-acts on our previously obtained knowledge, by resuming in a single statement all the four facts, and still more, by accounting for the failures of one or other of these in particular instances.

The faulty mixing up of description with causation is exemplified in the following sentences regarding Inflammation:—'Very often the pain is a "bulking" or throbbing pain—every beat of the heart makes itself felt in the tender part. The pain of inflammation *results no doubt, from the implication of the nerves in the diseased processes.*' 'Speaking generally, therefore, there is more pain felt in external inflammation, *because there are more nerves of common sensation.*'

It is next to be seen what better account can be given of inflammation, grounded on the superior physiology and observations of recent times. The definition of Dr. Aitken* is

* A complex morbid process characterized,—(1.) By a suspension of the concurrent exercise of function among the minute elements of the tissue involved; (2.) By stagnation of the blood and abnormal adhesiveness of the blood discs in the capillary vessels contiguous to the tissue-elements whose functions are suspended; (3.) By contraction of the minute arteries leading to the capillaries of the affected part, with subsequent dilatation and paralysis of the contractile tissue of the affected blood-vessels. The nutritive changes between the blood and the minute component elements of the affected tissue become visibly altered, and although an appreciable exudation does not necessarily follow, yet a constant tendency betrays

very exhaustive, but might be disburdened of various points more suitable to predication. The following appear to be the essentials of the enumeration.

(1) *Suspended function of the tissue involved.*—It appears from the observations, that an alteration of the tissue—such as to impair its proper functions, that is, its relations to the blood in the way of absorbing nourishment, and its secreting or other functions—is the primary fact, the starting point of the subsequent changes.

(2). *Stagnation of the blood.*

(3). *Abnormal adhesiveness of the blood discs in the capillaries adjoining.*

(4). *Contraction of the minute arteries supplying the capillaries of the part, followed by dilatation and loss of contractile power.*

(5). *A tendency to exudation*, varying according to circumstances.

Not until each of these constituent facts is made intelligible, and verified by references to observation, should any discussion be commenced as to their causative connexions among themselves, or with other facts. The description being first rendered complete and intelligible, there is the greatest interest in trying to show, for example, that the first fact—suspended function of tissue—leads to the blood derangements afterwards enumerated; and that the heat, redness, swelling, and pain, in the old enumeration, follow as effects from the train of circumstances, as given in the definition.

The new growths and deposits should be reserved for distinct predication. So also should be the cause or event of the attack, whether favourable or unfavourable.

The extreme variations of degree in morbid states, originate appearances scarcely short of differences of kind; and these have to be explicitly enumerated, as specific modes of the main phenomenon. A distinct consideration should be given to such an important accompaniment as fever, and to the con-

itself to the occurrence of an interstitial exudation, but which, under proper regimen and proper remedies, is often abortive. When an exudation follows as a result of the inflammatory state, it is apt to be associated with an unhealthy condition of the blood, and of the blood plasma, and to be associated with varied forms of new growth, according to,—(1.) The elementary structure in which it occurs; (2.) The special zymotic, constitutional, or local disease with which this complex morbid process may co-exist; and (3.) According to the progress of the inflammation, the amount and suddenness of the effusion, the extent of tissue involved, the diminished vascularity, and the powers of absorption of the surrounding parts.'

ditions of it (the chief being probably severity of the local attack, and poisonous virulence).

The hypothetical views started, in the absence of a theory, to connect the whole cycle of circumstances should be given last of all.

To frame definitions of *Degeneration* and *Functional Disease*, beyond the statement of the palpable appearances so named, would involve hypothetical considerations, such as require to be admitted into medicine, with due regard to their exact value.

Correlative with the definitions of Health and Disease generally, are those of the important words *Constitution*, *Temperament*, *Diathesis*, indicating a hypothetical permanent condition of the system, manifested by the tendency to incur or to resist diseases; and more especially diseases of enfeeblement and degeneration. A weak chest, a strong stomach, susceptible nerves,—are modes of stating in a useful form such actual occurrences, as that certain persons are easily affected with chest disease, or resist the agencies of stomachic disorder, and so on. They suggest the mode of life best fitted in each case to ward off attacks of disease.

Definition of specific Diseases.—The very general states above quoted exemplify definition under the greatest simplicity, as respects the number of characters, although not as respects the generalizing and seizing of the true characters. When we proceed to the more concrete forms of disease, Typhus, Gout, Pleurisy, Neuralgia, Jaundice, &c., we have the general processes, Fever and the rest, with many various accessories, constituting the specific characters of the individual affections. Consequently, the definitions are apt to be voluminous in their statement; and there is still more need of method.

Examples have now been given of the two different modes of medical definition; the one corresponding to Diagnosis, and framed with a view to identify a disease by such signs as are best accessible; the other, the most complete *generalization* of the essential fact or facts of the disease, which facts may or may not lie upon the surface. The first is requisite for distinguishing diseases; the second, for understanding them.

Let us take an example. *Gout* is defined by Dr. Garrod—'A specific form of articular inflammation, invariably accompanied with uric acid in the blood, and the deposition of urate of soda in the affected tissues.' The positions given to the words 'specific' and 'accompanied' suggest what was probably not in the author's mind. Strictly interpreted, the

language means—Gout is articular inflammation of a specific character (not described); it has, for concomitants, uric acid in the blood, and deposits of urate of soda. The real meaning must be presumed to be—Gout is articular inflammation, specifically marked by uric acid, &c.

This definition is one of those advanced generalizations, attained in some diseases, which penetrate to the essential features of the disease, without fully expressing the symptoms. A detailed account of the symptoms is therefore added, first under the title 'Description of an attack of Gout, and of the progress of the disease' (a sort of popular history of a case), and secondly, under 'Phenomena occurring during an acute Gouty Attack,' where there is a more rigid and systematic analysis into (1) Febrile Disturbance, and (2) Local Appearances.

Again, *Small-Pox* is thus defined (Dr. Aitken). 'The product of a specific and palpable morbid poison, which is reproduced and multiplied during the course of the malady. (1). After a definite period of incubation a remittent fever is established and followed by an eruption on the skin, and sometimes on the mucous surfaces, with other concomitant and occasionally succeeding affections (2). The eruption on the skin passes through the stages of pimple, vesicle, pustule, scab; and leaves marks or cicatrices on its site (3). The disease runs a definite course, and, as a rule, exhausts the susceptibility of the constitution to another attack (4)'

Here we have, in sentences (2) and (3), the leading symptoms of the disease, which, when elucidated at full, make up, as far as book description can go, the characters whereby the disease is known and discriminated. Sentence (1) does not properly belong to the definition, but to the predication; the cause of a disease must always be accounted a predicate. Sentence (4) contains two statements, first, 'the disease runs a definite course,' which surely is true of many other diseases, if not of nearly all; second, 'it exhausts the susceptibility of the constitution to another attack,' a most pertinent circumstance, but still better reserved for a predicate or concomitant, than mixed up with the defining marks.

Influenza is thus defined by Dr. Parkes:—'An epidemic specific fever, with special and early implication of the naso-laryngo-bronchial mucous membrane; duration definite of from four to eight days; one attack not preservative in future epidemics.' The transposition of the epithet 'specific' is desirable:—'An epidemic fever, specially characterized by

early implication, &c.' This definition also is a summary of symptoms, and nothing more. The author proceeds, under the head 'Symptoms' to describe the general course of the disease, and under 'Consideration of the Special Symptoms' to analyze them in the detail; Temperature, Condition of the Skin, Nervous and Muscular Symptoms, Respiratory System, Circulation, Digestion, &c.

All the facts stated in the Definition may be fairly allowed as defining circumstances, with the exception perhaps of the last 'one attack not preservative in future epidemics,' which might be reserved for predication. Doubtless, if we had a generalization of the central or fundamental fact of the disease, this would take place among deductive consequences, or propria. But we do not need it in a definition consisting of a summary of the symptoms.

The following sentence commences Dr. Buzzard's definition of *Scurvy*:—'A peculiar state of mal-nutrition, supervening gradually upon the continued use of a dietary deficient in fresh vegetable material, and tending to death, after a longer or shorter interval, if the circumstances under which it arose remain unaltered.' Here we have first a theory or hypothesis of the essence of the disease (a state of mal-nutrition), secondly, its cause, and thirdly, an announcement of its dangerous character. All this is extraneous to the definition, which is given unexceptionably (as a summary of symptoms) in what succeeds to the above quotation.

Propositions of Medicine.

10. The Real Predications of Medicine, as contradistinguished from the Essential or Defining Propositions, fall under distinct heads.

The coupling of the Essential characters, even although numerous, is Definition, and not Real Predication. Nay farther; the modified characters shown in different constitutions and different circumstances, should be held as a part, or as an appendage, of the Definition. Real propositions may arise in connexion with these modifications when certain circumstances are alleged to intensify or to resist the diseased action.

11. The first class of Real Predications comprises Inferences or propria from the Essential characters of a Disease.

Having given the defining marks, in their ultimate statement, together with the important modifications and varieties, we can by the help of general principles—Physical, Chemical, Biological, or Pathological—draw many conclusions bearing on the treatment of the disease. It would be easy, for example, to unfold a great many facts respecting Fever, from the Law of Conservation, the laws and facts of Organic Chemistry, &c. The maintenance of an excessive temperature, with less than the ordinary nourishment, involves waste or inanition of the organs, and the formation of special products of wasted tissue; with many other consequences under given situations. This deductive process, when based on well ascertained generalities, affords propositions capable of great precision and certainty.

12. The second class of Real Predications consists of the Causes of Disease.

A Disease is one thing, its cause is another thing; propositions of Causation, are, therefore, in their nature, strictly real. Their importance demands a distinct and separate enunciation.

Implicated with the great subject of Hygiène, or Health preservation, there is a body of information respecting the *General* Causes of Disease. It is all one thing to know what are the means to keep the body in health, and what will cause loss of health.

Many forms of disease are due at once to the disproportion between the expenditure and the nutrition of the system. The diseases of exhausted organs—functional weakness and degeneration of the muscles, the brain, the stomach, the lungs, the heart, the kidney—are of this class.

To the same general head should be referred nearly everything meant by Predisposing Causes of Disease. There are many diseases that do not spring up unless by poison or infection from without; called Zymotic Diseases. As the poison of many (but not of all) such diseases may be resisted by a healthy system, any circumstances that destroy general vigour, or weaken particular organs, are called predisposing causes; as when cholera attacks constitutions exhausted by intemperance, or by insufficient food, or by ill-ventilated dwellings.

It is less easy to generalize the various influences expressed as Infection, Epidemic poison, Miasmata, &c. This is one great field for Representative Hypotheses in Medicine.

Under each separate Disease, an account is given of the

Cause, as far as known, whether general or special. Whereever there is a loss of power from the predominance of waste over supply, Causation in Disease appears as 'Conservation;' it, however, still more largely implicates Collocations.

13. There may be a distinct class of Real Propositions, expressing the effects of Disease.

The full definition of each disease comprises its whole history to the termination; the temporary prostration of Typhus is not an effect of the disease, it is the disease itself. When, however, a disease, besides accomplishing its course, makes permanent changes in the organs or constitution of the patient, this is a distinct fact, and may be enrolled under the head of Causation. Such are the after effects of Small Pox, Measles, Scarlet Fever, and Syphilis. While a few diseases have a wholesome efficacy, the greater number weaken the system at some point, and are therefore predisposing causes of future disease.

14. The Remedies of Disease constitute Real Propositions.

All the previous classes of assertions prepare the way for the present. The remedy of a disease may be suggested by its Characters, whether primary (Definition), or inferred from the primary (Propria); or by its Causation, on the principle of 'remove the cause.' Diseases of functional degeneration, or premature decay of organs, involve in their cure 'repaying the debt to nature'—the restoration of the balance of nourishment and waste.

In many instances, the remedy consists in something different from either treating the symptoms, or removing the cause. The Specifics that have been discovered for particular diseases, as quinine, colchicum, lime juice, cod liver oil, are affirmed as independent facts, resting on no deductive inferences from Cause and Effect in Disease, but on the experience of their efficacy.

The Experimental Methods in Medicine.

15. All the Experimental Methods are applicable to Medicine, with certain cautions and qualifications.

The ultimate problem of Medicine is to find a remedy for every remediable disease; and the apparently direct solution is to try various remedies upon actual cases. If by Agreement, under a wide variation of circumstances, a certain remedy is

found to succeed uniformly, or in a great proportion of instances, there is proof that it is the remedy.

Still, we cannot but remark the very serious difficulties that beset all the Experimental Methods in this attempt. Plurality of Causes and Intermixture of Effects occur in the most aggravated shape. Moreover, drugs, being natural Kinds, have so many possible ways of acting, that the elimination of the precise property that affects the system is all but hopeless.

Without, therefore, abandoning the tentative process, as applied to actual disease, modern medicine has advantageously approached the problem in circuitous ways; and has instituted researches where the experimental methods are less likely to be defeated. Thus—to take the example that departs least from the empirical method—the mode of action of medicines and of remedies is studied by experiments, not restricted to special diseases, but applied to the system in health and in disease alike, under every variety of conditions. This is a far more thorough and searching procedure; and the Method of Agreement will, of itself, give trustworthy results under so great an extension of instances; while by superadding Difference, Inverse Agreement, and Variations, there may accrue results of the highest certainty. I may cite, among this class of Researches, the Report of Dr. Bennet on the Action of Mercury on the Biliary Secretion, and Dr. Harley's work on the Old Neurotics. By such researches is built up that part of Materia Medica relating to the Therapeutic action of medicines.

Again, the Pathology of Disease, the concurrence and sequence of symptoms, studied, in the first instance, apart from modes of treatment, is open to experimental enquiry, and may lead to results having all the precision attainable in the science of Medicine. For such enquiries, the Experimental Methods are suitable; the endeavour being made to bring each one of them into play, by searching for the appropriate class of instances. Mere Agreement is usually what suggests itself to the untutored mind; the force of Agreement in Absence and of Variations is apparent only to such minds as have reflected largely on the conduct of scientific researches.

The influences commonly called Hygienic, and the simpler Therapeutic agencies, as cold and heat, change, exercise and rest, stimulants, &c., not only present fewer difficulties to experiment, but are also within the scope of the Deductive method. In like manner, the proof of noxious agencies—as impure water, and the effluvia of decay—is easy and complete.

16. The Elimination of Chance is of great value in Medicine. Its groundwork is Medical Statistics.

Nowhere more than in Medicine may laws of Causation be defeated; there is rarely such a thing as a simple cause yielding a simple effect. Hence, the necessity of ascertaining whether a coincidence is more frequent than would be accounted for by chance. The cinchona bark sometimes fails to cure ague, yet its general efficacy is satisfactorily established.

To prove the efficacy of medicines as a whole, in opposition to some speculators that ascribe all cures to nature (aided by repose and regimen) the physicians of a French hospital made the experiment of withholding drugs from all the patients for a certain time. The conclusion seemed to be that the mortality was not increased, but the recoveries were more protracted. This was a competent inference from statistics.

The difficulties in obtaining a statistical proof of the action of a remedy in a given disease are exactly those already mentioned respecting the use of Agreement in the same determination.* A large hospital statistics is better than the inferences of a single physician in private practice, and yet may come short of the proof. There should always be obtained, if possible, a parallel statistics—cases with, and cases without, the treatment in question. The statistics of cholera treatment may be alleged in favour of many modes; but none appear to be decisively established.

Statistics, as applied to Scarlet Fever, has shown that a second attack is extremely rare; that the ages of two and three are most susceptible to the disease; and that the maximum of prevalence is in October, November, and December, and the minimum in April, May, and June.

The Deductive Method.

17. The scope of the Deductive Method in Medicine is co-extensive with the number of well-established generalities than can be appealed to.

The sciences applicable to Medicine—Physics, Chemistry, and Biology—yield a considerable number of these fertile generalities. The science itself contains few of a very commanding character, but a considerable number that have a sufficient range for deductive operation, and for converting empirical into derivative laws. All the propositions of general

* See an estimate of these difficulties in Dr. Barclay's work on Medical Errors, p. 35.

causation in medicine, the laws of general Therapeutics, the laws of the action of drugs on the system generally, have sufficient breadth to control and correct empirical practice; and the mastery of these, as well as of the more commanding principles of the preparatory sciences, increases the power of the physician. The physiology of Food as regards the various forces of the system, muscular, heat-giving, nervous, &c., and the products of elimination,—is pregnant with deductive consequences, both in warding off and in curing disease.

The experimental methods are greatly at fault with slow-acting causes; and hence deduction is pre-eminently desirable in such points as the influence of alterative medicines, stimulants, climatic influences, and modes of life. Only a thorough-going statistics, or a deduction from general principles, can dispose of the doubts that arise on such points.

Hypotheses in Medicine.

18. Medical Science is largely dependent on Hypotheses.

As a department of applied Biology, Medicine needs all the aids rendered by hypotheses in the mother science, and some special to itself. The great biological fact—Assimilation—takes on a new aspect in the production and spread of Disease.

The first and simplest case of Hypothesis, the assuming of an agent known to exist, but not known as present in adequate amount in the given case, is abundantly exemplified. Thus, the origin of contagious disease is ascribed hypothetically to various real agents, and among others, to actual living organisms. The effects tally in a general way with such an agency. What remains is to find whether they tally closely at all points. The hypothesis, however, receives a powerful support from individual cases where the presence of an animalcule, or living germ, appears to be actually established. The alternative, and older, hypothesis is that organic particles, in a state of change or activity, are thrown off from one living body and infect another, such particles not being complete organisms or the germs of organisms. This hypothesis may seem to assume less than the other, but in reality it assumes a class of particles not distinctly proved to exist. A strong analogy may be pleaded for them, in the supposed communication of morbid action within the system; the action of the poison of small pox must be the same on the blood of the innoculated patient as on the original patient. Yet the aerial effluvia of typhus may consist of something more

definitely organized than the supposed active particles. Fermentation by yeast is found to be due to an animalcule.

The Representative Fiction is indispensable in Medicine, and its rules and properties need to be well understood.

Diseased appearances, like all manifestations of living bodies, are the superficial outcome of a vast concatenation of hidden changes. These intermediate links are in great part unknowable; yet, by following the clue of what we know, we may so conceive or imagine them, as thereby to unite the appearances in a consistent whole. When an organ is liable to derangement from slight causes, we prononnce it *weak*, which is merely to express the fact in another word; when, however, we assign such circumstances as that its tissue has degenerated or changed, that it has very little tendency to assimilate nutriment from the blood, or that the superior exercise of all the other organs of the body withholds from it the fair amount of blood and nerve force,—we employ convenient hypotheses, which are more or less in keeping with the facts.

As regards the two leading diseased processes—Fever, and Inflammation—probably no hypothesis yet framed adds anything to the facility of conceiving or of generalizing the facts. Supposing the different fevers generated each by a specific virus, or animated body, we cannot even in imagination suppose a connexion between the structure of the infecting element, and the specific characteristics of the fever; as in the difference between typhus, scarlet fever, or intermittent fever. Indeed, we cannot form a plausible supposition as to the *intermediate* link that connects a certain infecting substance with the febrile state generally. The difficulty here is exactly the difficulty in representing the facts of living action.

Hypothesis appears to more advantage in connexion with what is termed Functional Degeneration, Functional weakness, strength and weakness of parts. Great convenience attaches to the use of such phrases as healthiness, robustness, vigour, constitutional force—which are modes of stating the absence of disease under circumstances that usually provoke it. We may increase the value of this class of terms, by hypothetical interpolations, to the following effect:—

Assuming an average healthy system to begin with, we know by reasonable inferences, (1) that every one of the organs needs an equable supply of blood, with more or less aid from the nervous centres, and (2) that each organ is capable of a certain amount of exertion. Suppose now, that by any cause, either the nutrition is below the mark, or the exertion above

it, or both. It is the nature of the system not to show immediately the effects of such a mal-proportion, yet there must be an immediate effect; the overwork, or the defective nutrition, of a single day does not leave the organ exactly as it was; we are entitled to assume that there is superinduced a minute structural change, or degeneration, perceptible only after many repetitions, but actually realized. Suppose the disproportion of expenditure and supply to continue for a length of time; the first outward symptoms will probably be, that the organ is enfeebled in some duty that is required of it, and becomes positively disordered under influences that, in its regular condition, it would have successfully resisted. At this point, degeneration or structural change has made a decided advance; another equal advance would bring down the organ to the bare performance of its functions; a third would be utter suspension and death. Now, we have here scope for a great variety of suppositions, as to the relative condition of all the organs in the body. We can represent the constitutional peculiarities at birth, by the proportionate dispositions of the several organs—nerves, muscles, lungs, digestion—to appropriate nutriment, and to become vigorous or the opposite; we can state to ourselves the practical mode of redressing the inequality, namely, by restraining the vigorous organs from their tendency to impoverish the rest, and by giving greater opportunity to the nourishment of the weak. We can also state the rationale of the constitutional treatment of diseases, viz., the placing of the weakened organs in such a position as to increase their nutriment and abate their over-exertion. We can give a hypothetical account of the degeneration of organs such as the heart and kidney, which often show no signs until the structure has reached a mortal disease. We should, moreover, feel no surprise at the sudden breaking down of constitutions reputed strong; the popular eye sees only the prosperity of those organs that cast a dash and a glare—the muscles, the stomach, and the brain. The deeper glance discloses the degeneracy of the heart, the lungs, the kidney, following on the very strength of these ostentatious members of the system.

Classification of Diseases.

19. There being upwards of one thousand recognized Diseases, they may, like other great aggregates, come under a regular Classification

Diseases may fall under a classified arrangement, like Minerals, Plants, or Animals, attention being given to the peculiarities of the department.

I. *Order of Characters.*—In Mineralogy, and in Botany, a strict order of characters is observed. This is disregarded in Zoology, and also in Medicine, from difficulties that can be readily assigned. There is every likelihood, however, that both sciences would gain by a systematic arrangement of characters, avoiding the sacrifice of the spirit to the letter.

In a work to be afterwards referred to (p. 367), the remark is made 'that the labour of analyzing and comparing clinical observations would be greatly lightened, and the precision of the observations themselves increased, if the records of these were in every instance *arranged on an uniform plan.*'

One obvious precaution is to make the outward symptoms precede the subjective. Thus, of the usual marks of inflammation, the pain should come last. In nervous diseases, the physical symptoms should be fully enumerated before entering upon the mental symptoms; the two classes are then viewed in such a way as to check and confirm each other.

II. *Maximum of Affinities.* — The propriety of classing Diseases by their closest resemblances is sufficiently allowed in the abstract; the difficulties in execution are not logical, but pathological.

III. *Arrangement by Grades.*—The formality of Grades is observed in the classification of Diseases, but without the full carrying out of what it involves. There is something of laxness attending the use of the method even in Chemistry, the statement of the points of community of the higher grades being sometimes given, and sometimes not, without any apparent reason.

Occasionally there is vacillation as to whether diseases are different in species, or mere varieties. Little importance attaches to the question; and the workable criterion is the comparative number and persistence of the distinctive marks.

IV. *Statement by Agreement and Difference.*—Everything already said on this head applies to the exposition of Diseases. The systematic and orderly stating of Agreements, and the pointed contrast in Difference, have the same efficacy here as elsewhere. Under the heading 'Diagnosis,' it is usual to mention the closely resembling diseases, and to indicate the diagnostic marks. For example, Roseola is distinguished from Scarlet Fever, thus:—the *eruption* in Roseola is generally confined to *the chest.* When the diagnostic points are

two or more, they might be set forth in the formal manner already exemplified.

20. V. *Index Classification.*—For Medicine, an Index Classification might be provided on the tabular plan.

This aid to the discrimination of Disease is still wanting. Probably, it would be best attempted, in the first instance, on the tabular plan. A basis is afforded in a small work, published by the Medical Society of Observation, with the title 'What to Observe in Medical Cases.'

The work professes to lay out in order an exhaustive statement of all the appearances connected with each bodily organ, besides adverting to the external circumstances of the patient. The enumeration commences with the Skin, which is followed by the organs of Locomotion, Digestion, Respiration, Circulation, Lymphatics, Urinary Organs, Organs of Generation, Brain and Nerves, Vascular Glands.

As an example, I quote the varieties of the Pulse:—'*Radial Pulse*:—number;—size and force; large, small, thready, equal, unequal, strong, feeble;—resistance; soft, compressible, hard, incompressible;—rhythm; regular, irregular, intermittent;—time as compared with that of heart's impulse;—artery tortuous, rigid.—Special characters of pulse; jerking, bounding, undulatory, continuous (one pulse appearing to run into the following), vibrating, quick, tardy, vermicular, tremulous, reduplicate.—Effects of posture on pulse (its number and other characters).—Phenomena of pulse in one arm as compared with the other.'

The authors have evidently studied exhaustiveness to begin with. It is possible, however, to be too minute; distinctions that are not marks of anything else are worthless and may be an encumbrance. The next step, therefore, should be to abridge and group the symptoms with a view to the *maximum of significance*.

There being obtained a methodical array of symptoms under each organ, the mode of proceeding with a view to an Index is to append to each symptom a list of the diseases where it occurs. Should a symptom appear in only one disease (as urate of soda in gout) the occurrence of the symptom would decide the disease at once. Should a symptom appear in three diseases, its occurrence points to one of those three diseases.

By appending, to every symptom of value in diagnosis, a complete list of diseases, there is provided a means of determining every disease according to the knowledge of the time. One symptom refers us to one list, containing two, three, or

four diseases ; a second symptom leads to another list. If on comparison, there is found only one disease common to the two lists, the diagnosis is complete. If there are two or three common to both lists, a third symptom must be sought out with its corresponding entries, by which the alternations are again reduced ; and so on, till the concurrence of symptoms points to a single disease.

Suppose, for illustration, that 'Irregularity of the Pulse' appears as symptom. According to Dr. Watson, this may attend (1) disease within the head ; (2) organic disease of the heart ; (3) simple disorder of the stomach ; (4) debility, and a prelude to stoppage of the heart's action from asthenia.

Now supposing the tabulation of symptoms and of diseases complete upon this plan, and supposing a second symptom in the case under enquiry had opposite to it a list, agreeing with the first only in the entry 'simple disorder of the stomach,' the diagnosis is made out by two easy references.

Owing to obvious causes—the great number of diseases accompanying particular symptoms, the occasional ambiguity of actual diseases by the failure of some of their usual symptoms, and the imperfection of the terminology of symptoms,—the best scheme that could be given would be imperfect. This would not, however, prevent it from being a boon to the student, and an occasional aid to the experienced practitioner. It does not supersede, but indicates, the reference to the systematic works on Medicine and Pathology, which are the authorities in the last resort.

BOOK VI.

FALLACIES.

CHAPTER I.

MILL'S CLASSIFICATION OF FALLACIES.

Mr. Mill regards all fallacies as divisible into two great heads—Fallacies of SIMPLE INSPECTION, and Fallacies of INFERENCE. By the first class he understands those cases where a presumption is created in favour of a fact or doctrine, on the mere inspection of it, and without any search for evidence; natural prejudices are comprised under that head. By the second class he understands erroneous conclusions from supposed evidence. This class is subdivided according to the nature of the evidence simulated; which may be deductive, inductive, &c. A special division is indicated under the title 'Fallacies of Confusion,' where the error arises, not in the link between premises and conclusion, but in the incorrect handling of the premises themselves.

There are thus five distinguishable classes of Fallacy, as set forth in the table:—

Fallacies	of Simple Inspection	-	-	1. Fallacies *a priori*.
	of Inference	from evidence distinctly conceived	Inductive Fallacies	2. Fallacies of Observation
				3. Fallacies of Generalization
			Deductive Fallacies	4. Fallacies of Ratiocination
		from evidence indistinctly conceived	-	5. Fallacies of Confusion

I. *Fallacies of Simple Inspection, or a priori Fallacies.*—Refraining from the discussion of the question, which this designation might raise, what are the ultimate facts or premises at

the foundation of all reasonings, Mr. Mill adduces first the tacit assumption that the same order obtains among the objects of nature as among our ideas of them—that if we always think of two things together, the two things must exist together. He illustrates this tendency by numerous popular superstitions, as 'talk of the devil and he will appear,' &c. He also cites—the philosophy of Descartes, which, from the mere conceptions of the mind, inferred the existence of corresponding realities; the doctrines that 'whatever is inconceivable is false,' 'that a thing cannot act where it is not' (applied by Newton to show the necessity of a gravitating medium), that 'matter cannot think,' that 'space is infinite,' that 'nothing can be made out of nothing,' that 'nature always acts by the simplest means.' An allied Fallacy, or prejudice, is the tendency to presume a correspondence between the laws of the mind and the laws of external things, of which one form is expressed thus:—'whatever can be thought of apart exists apart.' From this springs the personifying or re-ifying of Abstractions, as in the doctrine of Realism, and in mystical theories generally, whether it be the mysticism of the Vedas, or the mysticism of Hegel; all which proceeds on ascribing objective existence to subjective creations—feelings, or ideas.

Another kindred fallacy consists in representing nature as under the same incapacity with our powers of thought; the great example being the celebrated Principle of Sufficient Reason, adduced in explanation of many first truths, such as the laws of motion.

'That the differences in nature correspond to the received distinctions of language,' is another wide spread and baneful prejudice, which particularly weighed upon Greek philosophy, being prominent in the reasonings of Aristotle, and from which Bacon was unable to set himself free, as is shown by his futile attempts to find a common cause for everything that goes under a common name, as heat, cold, &c.

Lastly, there has existed the prejudice that 'the conditions of a phenomenon will resemble the phenomenon'—like producing like: as that motion must necessarily arise from the impact of a moving body; that a sharp taste must be brought about by sharp particles; that our sensations must be copies of external things; that the law of causality can hold only between what is homogeneous, whence there can be no causation between mind and matter; that the Deity must have the exact perfections discoverable in nature.

II. *Fallacies of Observation.*—These do not apply to the

operation of observing, for which there is no logic strictly so called, but to the omissions and partialities in collecting facts with a view to the *generalizing* process. There may be Non-observation, or Mal-observation; the one leaves out pertinent instances, the other distorts or misrepresents what is observed. Non-observation explains the credit given to fortune-tellers, to quacks, and to false maxims; the cases favourable being noted, and the other forgotten. The motive in this class of fallacies is a strong pre-conceived opinion or wish to find the dictum true. Farther, the Non-observation may be, not of instances, but of *material circumstances*, as when it is stated that lavish expenditure alone encourages industry, the circumstances being overlooked that savings are capital for the employment of labour.

Under Mal-observation may be placed the chief mistake connected with the proper act of observing, namely, the confounding of a perception with a rapid inference, or the mingling up of inferences with facts. This is the common infirmity of uneducated witnesses and narrators of events.

III. *Fallacies of Generalization.*—These are errors in the employment of the Inductive process. The chief instances adduced are these:—All inferences extended to remote parts of the universe, where no observation or verification can be carried; all universal negatives and propositions asserting impossibility (not being contradictions in terms), the theories professing to resolve all things into some one element, of which the most notable instance is the attempt to resolve states of consciousness into states of the nervous system; the placing of empirical laws, arrived at *per enumerationem simplicem*, upon the footing of laws of causation, largely exemplified in reasonings upon society; the vulgar form of the same fallacy, designated *post hoc, ergo propter hoc;* and the fertile class of False Analogies. Under the same head are specified Bad Classifications, or the asserting under one term, things that have little or no community; of which the Greeks gave examples in such terms as Motion, Generation and Corruption.

IV. *Fallacies of Ratiocination.* These comprise the errors against the laws of the Syllogism. Mr. Mill, however, properly includes under them the fallacies connected with the Conversion and Equipollency of Propositions; remarking that the simple conversion of the universal affirmative, and the erroneous conversion of Hypotheticals are among the most frequent sources of error. Of this last class, is the maintenance of some favourite doctrine, on the ground that the inferences from it

are true. Connected with the Opposition of Propositions is the confounding of the contrary with the contradictory of a statement. Vicious syllogisms, whether from *undistributed middle*, or from *illicit process*, are the more noted instances of this class of fallacies. There may be also included the fallacy of *changing the premises*, occurring frequently in the argumentative discourses of unprecise thinkers (the schoolmen's *a dicto secundum quid ad dictum simpliciter*); exemplified in the once favourite theory that 'whatever brings in money enriches.' Under the same head might be placed the misapplication of general truths, or the supposition that a principle true in the abstract must hold under all sets of circumstances.

V. *Fallacies of Confusion.* The first class under this designation is *Ambiguity of Terms.* As there is no limit to that form of confusion, a logician can only select a few random instances; those chosen by Mr. Mill are 'scarcity of money,' 'influence of property,' 'theory,' 'the church,' the '*laudable*' in a Stoical argument in Cicero's *De Finibus*, 'I' in Descartes' argument for the being of God, 'necessity,' 'same,' 'force,' 'infinite,' 'right;' to which he adds examples of the fallacy of Composition and Division, as strictly belonging to the same class.

The second division is *Petitio Principii*, otherwise called 'arguing in a circle,' of which there are abundant examples. A certain species of terms received from Bentham the designation 'question-begging appellatives,' because they begged a question under the guise of stating it; such is the word 'Innovation.' Plato, in the *Sophistes*, has an argument to prove that things may exist that are incorporeal, because justice and wisdom are incorporeal, and they must be something: thereby begging the question that justice and wisdom are things existing apart or in themselves. One of the most remarkable examples of fallacy is furnished by the political theory of Hobbes and Rousseau, known as the theory of the 'social compact.' We are supposed bound by the promise entered into by our ancestors before society was called into existence; but there is no such thing as an obligatory promise until society has first been formed.

The third class of Fallacies of Confusion is the *Ignoratio Elenchi.* It is exemplified in most of the replies to the population doctrines of Malthus. A still more signal instance is the stock argument against Berkeley's doctrine of the non-existence of matter; Johnson's kicking the stone was not the point denied in the ideal theory.

CHAPTER II.

THE POSITION OF FALLACIES.

The setting apart of a distinct chapter to the consideration of the errors against the laws of reasoning and evidence seems at first sight an incongruous proceeding. We cannot separate a law from its violations; the one implicates the other. When good reasoning is exhibited, there must be exhibited at the same time the coresponding bad reasoning. If the rule be given that the middle term of a syllogism must be distributed once, whoever understands the rule must conceive, at the same time, cases of its fulfilment and cases of its non-fulfilment. If the method of Difference requires that the instances compared shall coincide in every particular save one, we are instructed by it that the method fails if any two instances do not coincide to this extent. If a good classification involves identity on one or more points of importance, there is implied in the same statement that a grouping under one name, without any important community, is a bad classification, a 'fallacy' of classification.

Any one would recognize the absurdity of a grammar that would reserve for a chapter at the end all the examples of grammatical errors. Yet such is apparently the plan pursued in Logic. The grammarian, indeed, frequently provides a separate collection of errors by way of practice to the pupil, but these are additional to what necessarily and properly occur under the rules that they severally violate; this, however, is not avowed by the logician as the nature of his chapter on Fallacies.

Without entirely exonerating works on Logic from the inconsistency of distributing between two departments of the subject the fulfilment and the violation of the same rules, we can assign certain circumstances that account for the prevailing usage. The main circumstance is the narrowness of the field of logical precepts, from Aristotle down to the present generation. The part of reasoning reduced to rules was almost exclusively restricted to the syllogistic or deductive departments; hence, in the exemplification of those rules, no errors could come to light except such as violated the forms

of syllogism. But the Greeks had surveyed human knowledge wide enough to be aware that many errors passed current that could not be reduced to errors of syllogism. The logician, therefore, was driven to one of two alternatives—to make no allusion to some of the most notorious failings and mistakes of the human understanding, or to provide a chapter for enumerating such mistakes entirely apart from the body of logical theory. It was characteristic of Aristotle to choose the second alternative—to be inconsistent rather than to be incomplete. His treatise on Fallacies comprises errors against the Syllogism, which he could not omit noticing under the Syllogism (Undistributed Middle, Illicit Process); but these are a small part of the mass of Fallacies; and the rest he had not any theory for. He had no Inductive Logic (or only mere traces which his followers wiped away), and therefore he had no place for the exhibition of the rules sinned against by *post hoc, ergo propter hoc.* For want of a thorough-going discussion of the department of Classification and Definition, he could not exhibit the errors connected with general language under precepts for the classifying of things and the defining of terms.

It has been seen, however, that even the thorough-going Logic of Mr. Mill does not dispense with a 'Book' on Fallacies. This is explained in part, but only in part, by the author's adhering to the usage of all former logicians, while using his own extended system to re-arrange the recognized examples, and to introduce new ones. Yet all the fallacies in the second, third, and fourth classes (Observation, Generalization, Ratiocination) might with the utmost propriety be absorbed into the body of the work. The account of the inductive and deductive processes unavoidably quotes derelictions from the sound performance of these processes, which derelictions are identical with the fallacies treated of under the heads just named.

The case is different with Mr. Mill's first and last classes (Simple Inspection and Confusion). The chapters on these heads contain matter that would not readily find a place in the systematic exposition of the logical methods. To take the first class, Fallacies of Simple Inspection, or *a priori.* Under these, the author dilates on certain fallacious tendencies of the mind, the generating causes of errors. Now, the logician might say that his business is to show how errors are to be checked and corrected, not how they arise in the imperfections of the human constitution. If he is to handle this subject, he

could not with propriety take it up in the detail of the Deductive and Inductive Methods; he would need to be allowed a corner apart. The demand is irresistible. It would be most inexpedient to agitate, under the Syllogism, or under the Experimental Methods, enquiries as to the fallacious tendencies of the natural mind. Granting that all the deductive and inductive fallacies, and the mistakes of classification and definition, were taken up into the main body of the work, the fallacies *a priori*, if included at all, must receive a separate handling. Some doubts might be raised as to the logician's title or obligation to enter upon the subject, but there could be none as to his allocating a distinct chapter to the consideration of it.

Socrates was the first person to urge strongly the natural corruption of the human intellect, and the need of a very severe remedial discipline, which, in the shape of personal cross-examination, he was wont to apply to his fellow Athenians. The theme was not again taken up in a vigorous manner, until Bacon composed the first book of the Novum Organum. The elucidation of the inevitable miscarriages of the untutored understanding, *intellectus sibi permissus*, and the classification of *idola*—false lures, in that renowned work, instead of being laid to heart and followed up by fresh examples, became a matter of mere parrot repetition. The next person to treat the subject independently, and to go systematically over the ground, was Mr. Mill, in his chapter entitled 'Fallacies *a priori*.' So important is the subject, and yet so far is it distinct from the proper field of Logic, that it might be embodied in separate treatises. It is a kind of homily or preaching, a rousing address on human frailty; and although the logician is the person most likely to be impressed with the evil consequences, he is not the only person qualified to illustrate them; while the points to be adduced in the exposition are not precisely such as fall under either the deductive or the inductive logic.

Mill's concluding head 'Fallacies of Confusion,' still remains *extra-logical*. The extension of the field of logic does not enable this class to be absorbed. They cannot be adduced as violating inductive, any more than deductive precepts. In reality, they are owing to the defective acquaintance with the subject matter of the reasonings, and to a low order of intellectual cultivation generally, rather than to misapprehending logical method. A considerable stretch of the logician's province is implied in the taking up of this class of errors. The ground that they

cover is boundless and indefinable; no man can foreshadow the intricacies, the incoherences, the perplexities, the entanglements, possible to the human understanding. The only circumstance that justifies the attempt to handle them systematically is the great frequency of a few leading forms; in consequence of which they can be, to some extent, treated comprehensively. Mr. Mill's three classes of examples—Ambiguous Terms, Petitio Principii, Ignoratio Elenchi—have this character of extensive recurrence. Moreover, in the elucidation of such classes, there come to view many prominent and practical errors, thus opportunely laid bare.

From these considerations, it follows that the most defensible course to be pursued in regard to Fallacies is to absorb into the main work all those that are the direct violation of logical precepts; and to handle, in the chapters apart, the Fallacious tendencies of the human mind, and the Fallacies of Confusion. This is not to debar the assembling of additional examples in a supplement or appendix; it being understood that these are merely in continuation of the examples already furnished in the regular course.

CHAPTER III.

FALLACIOUS TENDENCIES OF THE MIND.

The Fallacious tendencies of the mind may be traced through an enumeration of the sources of Belief.

The state of Belief is a form or manifestation of our activity. The import and measure of Belief is the readiness to act in the direction indicated by the thing believed. A man's belief in the wholesomeness of a regimen is shown by his energy and persistence in adhering to it.

There are three distinct sources of belief. I. The inherent Activity of the System—the disposition to act through mere spontaneous vigour. II. The influence of the Feelings, Emotions, or Passions. III. The Intellectual Associations, or acquired trains of thought. Excepting under the last head, there is nothing to guarantee *soundness* of belief, or the accordance of the thing believed with the reality.

I. *Inherent Activity of the System.*

From the spontaneous and inherent vigour of the system, we are induced to act somehow, to change out of the passive into the active condition, and to continue that activity while the energies are unexhausted, and while there is freedom from obstruction. There is no enquiry beforehand as to the proper course or direction to act in; opposition is not presumed until actually encountered. A way now open is supposed to be always open; the mind does not anticipate any future termination or obstacle. Blind confidence is the primitive attitude of our mind. It is only through the teaching of experience that we suppose any limit to our career of action.

This state of mind shows itself in our early beliefs, which may be described generally as over-vaulting; as presuming that what holds now and here, will hold then and there and everywhere. The following are instances :—

We are disposed to assume that, as we feel at the present moment, we shall feel always. After a certain number of checks, the tendency is somewhat restrained, but it continues very strong all through early life, and is seldom entirely conquered at any age.

We begin life by reckoning with the utmost confidence that other persons feel exactly as we do. After lengthened experience, this primitive tendency is greatly subdued, although perhaps in few minds is it fully sobered down to the measure of the actual facts. The consequences are shown in our not allowing for differences of character, in our inability even to conceive of types departing widely from ourselves. Without being the sole origin of intolerance, this tendency greatly ministers to that prevailing vice of mankind. We can with difficulty avoid judging all men, in all circumstances, by the standard suited to ourselves and our own circumstances.

From one or a few instances we are ready to infer a law applicable without limit. The mere infant parodies the inductive process; the most ignorant of human beings are the most unrestrained generalizers. From an acquaintance with one or two Frenchmen, Italians, or Russians, we conclude the characters of the entire nation. We feel assured that a remedy found to answer in a particular case will answer universally. Happening to visit a place during fine weather, we are led to suppose that the weather there is always fine. The word 'always' is a familiar expletive to vent our generalizing temper.

We presume that the state of things familiar to us, prevails everywhere. Not only are we indisposed of ourselves to anticipate and conceive different arrangements, natural and social, but we hold out against the very existence of such. The king of Siam's energetic repudiation of ice was a genuine display of the natural man.

Without making formal generalizations upon a single instance, we are disposed to outrun our facts, to extend the present into the distant and the future. It is always more congenial to make leaps in the dark, than to abide strictly by what we actually know. We have no sympathy with any one proposing to restrain gravitation to the solar system, where it can be proved to operate; our natural desire is to extend it everywhere, with or without positive evidence.

To identify, to assimilate, to generalize, constitute one of the two great functions of science. Yet there is often a necessity for restraining the too great ardour for these processes. We identify and assimilate, without real likeness, thus giving birth to bad analogies, and irrelevant comparisons; we over-assimilate and over-generalize. We rush blindly on the search after Unity, Simplicity, Fraternity.

It is a result of the primeval tendency to follow out a lead to unbounded lengths, that we so strongly assert the Law of Causation, irrespective of the facts that have gradually established its certainty. We have a *subjective* assurance that bears no proportion to the *objective* proofs. We shall never be in a position to assert the law, by the force of legitimate evidence, with the confidence that we feel respecting it.

That human nature is the same in all ages is affirmed, not from a careful examination of the records of the human race, but because the affirmer has not laid himself in the way of checks to the natural tendency to reason from the near to the distant. The doctrine is more behoven to ignorance than to knowledge.

The most of Mr. Mill's Fallacies of Simple Inspection are referable to the tendency now discussed. That 'we should make our thoughts the measure of things,' which is done in so many celebrated speculations, is the result of the inherent pushing activity of the system, the determination to proceed in a course once entered on, until a check is met with, and even in spite of a good many checks. 'That the conceivable is necessarily true,' and 'the inconceivable necessarily false' are merely various expressions of the same fact.

The supposition that 'the effect resembles the cause,' that

'like produces like' also grows out of the mind's incontinent tendency to assimilate, or identify, the repugnance to depart from a familiar type until compelled by a power from without. The reasonings of ancient philosophy frequently exhibit this fallacy, especially in the subject where it has most frequently operated, the relations of mind and body. Thus Aristotle reasons that Intellect, as well as Sense—must be corporeal, since it has to deal with corporeal things; and Like can be comprehended only by Like.

II. *Influence of the Feelings.*

The perverting influence of the Feelings, in matters of truth, has been more generally noticed, than the perversions due to inherent activity. That men have in all ages been biassed by their interests, their fears, their antipathies, their likings, their poetic ideals, their religious sentiments,—is one of the most widely-received and least contested doctrines of human nature. Many of Bacon's *Idola* are prejudices of the feelings; the *idola theatri* relate to the poetic, artistic, or ideal cravings of the mind; the *idola tribus* (which would properly include the other) comprise all the fallacious tendencies common to men generally, in opposition to individual peculiarities (*idola specus*); they therefore necessarily include the feelings. Mr. Mill gives fewer illustrations of the influence of feeling, than of the influence of activity as above explained.

The operation of the feelings is partly through the will, and partly on the intellect. What gives us pleasure urges the will for its pursuit; and our activity, in whatever way prompted, carries belief with it. We believe that the things that we like are free from harm, if not beneficial—our favourite dishes, stimulants, amusements. The effect of liking is to induce action in a given course, which is a power for belief, able to surmount a certain degree of hostile evidence.

The obverse is also implied. What offends, annoys, or displeases us is avoided; the will is against it; and we have a corresponding difficulty in believing it to be a proper object of pursuit, or in any way commendable.

The other mode of working on the feelings is through the Intellect. A strong feeling, whether pleasurable or painful, occupies and detains the thoughts, and excludes for the time all other subjects. If it be pleasurable, the detention is at the maximum; but even pain has power to engross us. Hence, under great excitement, thoughts alien to the state of feeling of the time, are not allowed to rise to the view; we judge

upon one-sided facts and views. An orgie of pleasure renders us unable to entertain disagreeable facts; a fright allows us to see nothing but danger.

The present purpose will be served by the following enumeration of perverting states of feeling: (1) Self-interest generally; (2) Sympathy; (3) Special Emotions. Such is the order found convenient for illustrating the Oratory of the Feelings (English Composition and Rhetoric, p. 201).

Self-Interest.—This comprises our pains and pleasures generally (to the exclusion of our Sympathies), whether from sense, from emotion, or from the associated and comprehensive ends, as Wealth and Power. That men believe according to their self-interest hardly needs illustration. Not only does each man endeavour to deceive others, he generally succeeds in deceiving himself when his interests are at stake. We have all great difficulty in seeing the faults of an institution that we profit by; the arguments of a highly paid priest for his own form of religion, or of a lawyer for lucrative forms of procedure, are regarded with suspicion. The grossest forms of error, the most noxious practices will be vindicated by persons whose worldy position depends upon them.

Among the particular pleasures and pains making up the great aggregate of self-interest, we may signalize some as especially unfavourable to truth. Indolence, or the aversion to labour, the source of so many moral obliquities, is the parent of intellectual error. The ascertainment of truth demands a kind of labour that the average human being dreads and abhors; hence the acquiesence in such views as come easiest to hand. That unqualified extension of the present to the distant, the past, and the future, which we have seen to grow out of the inherent activity of the system, is still farther recommended by the saving of toil. Excessive identification, generalization, and simplication are other expressions for the same tendency; while complication, and incoherent details, are preferred to a simplifying generalization that would cost great labour.

One form of self-denial requisite for getting at truth is to withstand the influence of the present, and the palpable. A present impression has a commanding potency. The inherent tendency to assume that what is will be, is aggravated by any unusual impressiveness of the present fact. The first victory of a campaign elates the conquering army with confidence in the future.

The Sympathies.—The sympathetic tendency of our nature while antagonizing self-interest, and the errors thereby induced,

is a source of errors peculiar to itself. In making us chime in with the feelings and views of those about us, it perpetuates opinions that have once got a footing; so that the world is sometimes dependent for a move in advance, on the revolt of an excessive egotist.

The disposition to see as much good as possible in our fellow-beings has nursed various fallacious judgments. Thus it is said of errors, that they are almost always partial or half truths; which may be the case with certain errors, but certainly not with all, probably not with the majority. An error has usually some show of fact to rest upon; but we cannot say that the ante-copernican doctrines of Astronomy were half truths; that the sun and stars move round the earth, was a total mistake. That despotic government favours the happiness and the improvement of mankind does not deserve to be called a half truth. It is the conversion of a few exceptional instances into a general canon.

Another fallacy of excessive sympathies is that what has been in the past has always been more or less suitable to the time and circumstances. Thus, slavery, it is said, however disapproved of now, was once necessary and suitable. Persecution for opinions was the fitting accompaniment of an early state of civilization. Feudality and hereditary monarchy may now cease to be essential, but were so in former times. Such encomiums on the past need to be received with great misgivings. To justify them fully, we must maintain, first, that the good of mankind has been the chief motive of the founders and supporters of the actual institutions of every age; and, secondly, that men's ingenuity of contrivance has been always on a level with their necessities. We cannot say that it was essential to human society that the Greeks of the time of Pericles or of Xenophon should be sold as slaves, when they happened to be taken in war; such men could have been induced to work by the motive of pay.

The Special Emotions.—The consideration in detail of a few of the leading emotions will bring to view the more specific sources of fallacy arising from the feelings. Their operation is still mainly due to their being pleasures or pains; although there is in emotion also the influence of mere excitement, irrespective of pleasure, in occupying the mind and directing the trains of thought.

We may remark first on the Emotional Temperament generally, or, as it is also called, the *Sanguine Temperament*, the effect of which is to dwell upon the good side of every-

thing. Men endowed with this peculiarity over-estimate all that is good in their prospects, and in the prospects of the world generally. They are optimists as regards both the present and the past. They fall into the last named error—that whatever was, was right. Mere sympathy, without the sanguine temperament, might not so readily fall into that mistake. The opposite temperament works in the opposite direction; it is the source of disheartening views of things, and forebodings of disaster. The fluctuations of the mental tone in each individual have temporarily a like influence on the beliefs.

The emotional temperament indulges in delightful ideal conceptions, from which are excluded the stern features of the reality. Hence the fallacious picture of a beneficent despot—the blessings of absolute authority in good hands—which occupies the minds of sentimentalists, and plays into the hands of real oppressors.

The emotions of Novelty and Wonder have been often descanted on as sources of corruption. They disincline men to any facts, views, or theories, that have not in them a dash of the marvellous. It is difficult to get good observations on the mental faculties of the lower animals, from the wish to invest everything about them with mystery and wonder. The same cause preverts the records of travellers in foreign countries. Even physical phenomena that have anything marvellous about them are difficult to observe with precision; and the statements of unscientific persons are generally untrustworthy. The fondness of the human mind for exaggeration and hyperbole renders a great part of human speech untrue to fact.

The Emotion of *Fear*, superadded to mere aversion or disliking, unhinges and debilitates the mind, disposing men to dark and dismal views of things, and fitting them to be the slaves of whoever has the power to terrify. Under the shape of Superstition, the susceptibility to fear has held mankind in captivity to innumerable delusions, especially in all that pertains to the supernatural. As the enemy of science, superstition is dwelt upon by Bacon with peculiar emphasis.

The feelings of *Love*, tenderness, affèction, amiability, which are distinct from sympathy proper, although always in some degree fused with it, are corrupters of the intellect, by creating a disposition favourable to whoever is loved; hence the partialities of affection and friendship, the incapability of seeing anything wrong in one's country, sect, or party. In the

higher compounds, termed Admiration and Reverence, there is a still greater power to sway the judgment of the individual. Deference to great authorities, and to the prevailing views of society, and the readiness to admit compromises, may be traced to the loving and sociable dispositions. The same dispositions are easily led into the worship of antiquity, which is the sentimental stronghold of blind conservatism.

The emotions of *Self*—the special circle of Vanity, Conceit, Pride, Feeling of Dignity—in proportion to their power, disturb the judgment of what is true. The respect for our own opinions, because they are ours, the plans, devices, theories of our own concocting, the value set upon everything that touches ourselves,—are snares in the way to truth. Our egotism even comprehends family, friends, party, and nation; to all of whom, as being related to ourselves, we attribute a superior wisdom. National prejudice is one of the great obstructives of political progress.

The sense of *Personal Dignity* operates to pervert our views in a remarkable degree. Many prevalent doctrines are recommended by their supposed contribution to the dignity of human nature. A leading argument in favour of the Immateriality of the Mind or Soul is expressly grounded in the greater dignity of the immaterial essence. The doctrine of Free-will is supposed to elevate human nature by the ennobling function of autonomy, self-government, or judicial arbitration. The modern hypothesis of Development is objected to as offending our ancestral pride. The exceeding sinfulness attributed to human nature by the Calvinist would be highly unpalatable, but for the tribute indirectly paid to our self-importance.

Our emotions of *Anger*, like Fear, are manifestations superinduced upon mere pain. Revenge, antipathy, hatred, party spirit, are forms of the irascible feeling, and are antagonistic, in a conspicuous degree, to the ascertaining of truth. Calumny, the expression of anger, connotes falsehood.

We may conveniently group under the *Æsthetic Feelings*, a variety of emotional states, of which the central and special mode is Artistic Harmony, but which involve also many of the other emotions—as Novelty, Wonder, Love. They are the emotions aimed at in poetry and in works of Art, and contain a large mass of powerful feeling. Many false systems of philosophy, and numerous petty errors and perversions, are to be ascribed to this department of our emotional susceptibilities. Thus in the ancient world, the minds of philosophers were dominated by the idea of symmetry, proportion, order,

and harmony. Pythagoras was entranced by the mystery of number; Plato followed him; and Aristotle was not exempt from the spell. But the predominant source of fallacy quotable under the present head was the supposed Perfection, Dignity, and Becomingness of certain arrangements in nature, which included numerical considerations among others. The superior worthiness of fire was declared in the Pythagorean philosophy; and even in the later Copernican controversy an argument was founded on the circumstance that the new system placed fire, the noblest element, in the centre of the universe. So only Mind, according to Plato, in Philebus, is sufficiently dignified to create the world. In the recital by Socrates, in Phædon, of the phases of his intellectual history, on the subject of Cause, the doctrines of Thales and Anaxagoras are set aside because they do not recognise the *becoming* as a power in the world. The adherence to the circular form of the planetary orbits, because of its perfection, was inveterate in the cool mind of Aristotle. The planets could be only six, because that was a perfect number.

The dictation of a plan to Nature on a supposed propriety has run through all times. Even in hard business affairs of trade, Aristotle held it was against nature that money should breed money, that is, pay interest on loans. Lamarck argues that a Polype cannot have Sensibility, because it would be contrary to the plan that Nature is obliged to follow in all her works (Lewes's Aristotle, p. 97).

The fiction of Unity, which carried away the early Greek philosophers, partly proceeds from over-assimilation, and partly ministers to artistic emotion. The absolute unity of mind is still worshipped by German philosophers. Herbart and others, rather than admit the radically distinct nature of Feeling, Will, and Intellect, insist upon regarding Intellect or Cognition as the basis of the two others.

The artistic sublime dictates such exaggerations as 'Let justice be done, though the world collapse;' 'Truth is great and all-prevailing.' Only a mind driven off its calm centre by the sublime of Force can exclaim 'Might is Right.' The fallacy that makes Artistic Harmony the test of truth, almost inevitable in poetry, is deliberately maintained in Wordsworth's Essay on Epitaphs, and in his prose criticisms.

The allegation is often made, on instances garbled to chime in with an amiable sentiment, that great men derive their mental power chiefly from their mothers.

The influence of æsthetic qualities—beauty, sublimity, har-

mony, propriety—is constantly operating to twist the understanding. The architecture, music, and colouring employed in religion, indispose the worshipper to canvass the validity of the doctrines. The art of the orator involves the tickling of the sense, and the charms of style. Such subjects as History, Criticism, Morality, the Human Mind, where literary polish is more or less attended to, are liable to distortion through that circumstance. Of Rhetorical devices, only a few are subservient to truth; while a great many are hostile.

The interests of Morality and Religion, have, in almost every age and country, been thought to require a habitual exaggeration of the pleasures of virtue and the miseries of vice. Plato was the first openly to recommend the pious fraud of preaching doctrines, in themselves false, as being favourable to morals and social order. And although only one society in modern times—the Jesuits—has formally avowed the same principle, there has been a wide-spread disposition to put it in practice. Various apologists for Christianity have contended that, even supposing it untrue, it ought to be propagated on account of its beneficial consequences.

III. *Influence of Associations.*

Belief is not founded in the intellect; yet the intellectual associations confirm tendencies pre-existing, and contribute to belief both in the true and in the false. When two things have been often associated together in the mind, the impetus thus acquired, in passing from the one to the other, counts as a force of belief. We are disposed, by our inborn activity, to proceed upon whatever we are told, there being no counteracting tendency present; the frequent repetition of the same declaration enhances our disposition to believe it. The force of iteration is one of the leading causes of men's beliefs. What has often been said, and seldom or never contradicted, is all-powerful with the mass of mankind.

Thus, one part of the influence of education, and of prevailing opinions, is due to an intellectual link, whose growth could be arrested by mere counter iteration. The same influence is at work confirming our modes of looking at things. There may be no reason, beyond the adhesion generated by length of time, why a man is reluctant to entertain a new opinion, and yet this may be enough to render his conversion impracticable. It was remarked that Harvey's doctrine of the circulation was admitted by no physician past forty. Among our habits, we are to reckon beliefs. The inveteracy of preconceived opinions is in great part due to their being long cherished.

CHAPTER IV.

FALLACIES OF CONFUSION.

These fallacies cannot usually be produced as direct contraventions of logical method. Many of them depend on imperfect acquaintance with the subjects under discussion. A certain number may be regarded as snares of language (Bacon's *idola fori*). A logical discipline is good as against many; and their detailed exposure may have a slightly fortifying influence. As already remarked, an exhaustive treatment is not possible; but certain genera may be selected as being both prevalent and deleterious.

Fallacies of Language.

Ambiguous and ill-defined terms.—The Fallacies of Equivocation of the scholastic logic are fallacies of ambiguous language; for which the remedy is an exact definition of all leading terms, and an adherence to the meaning so settled.

It is one criterion of an advanced science to have its terms defined. In subjects not raised to scientific precision, we may expect vagueness in the use of language. The Mathematical and the Physical Sciences were the first to make progress in this direction; only in recent times has the progress been extended to the Moral Sciences—Psychology, Ethics, Politics, Law, Political Economy.

The exemplification of ambiguous words has no limit, unless we adopt some principle of selection. For a work on Logic, the most appropriate examples are terms of leading importance whose ambiguity is still a cause of error and perversion.

The word 'Nature' is full of ambiguity. Butler pointed out three meanings. Sir G. C. Lewis, after a lengthened examination of particular uses of the word, found that they fall under two classes:—(1) A *positive* idea, as expressing essence, quality, or disposition; (2) A *negative* idea as excluding art, or human regulation and contrivance. This last meaning occurs in the phrase *state of nature*, used to designate man's existence before the introduction of law, government, and the arts of civilization. As human interference may sometimes be

good and sometimes bad, the meaning of nature varies accordingly. When men's 'natural rights' are spoken of, there is great doubt as to what is intended. 'Every man has a natural right to his liberty'—is a jumble of uncertain sounds; 'natural' being probably used in Lewis's second acceptation, as the antithesis of art, regulation, and interference.

'Liberty' has various meanings. It is not merely the absence of coercion or restraint, as being at large instead of being imprisoned; it extends also to the possession of powers, rights, and status; thus in a community where there are slaves, being imprisoned; it extends also to the possession of powers, liberty is a distinction, and freemen compose a privileged order of the state.

The ambiguities of 'Moral' have been previously adverted to. Even in the one specific meaning of 'right and wrong,' it has a fluctuating signification, and has given occasion to erroneous views. The criterion of 'moral' and 'immoral,' in the accurate meaning, is Law; a moral act is imposed by a superior; hence a supreme power cannot do an immoral, any more than an illegal act. When the Deity is said to have a 'moral' nature, the word must be supposed to mean simply 'goodness,' or else 'equity,' both which qualities may attach to a supreme legislator; the sovereign power may do a mischievous act, and may be guilty of partiality or unfairness as between one man and another; which, however, is not the connotation of immoral or illegal, according to the proper definition of the terms. The sovereign has no moral duties; his acts create these for his inferiors.

The confusion of Law in the juridical sense, with Law as the uniformity of nature, is exemplified in Butler's chapter on the Moral Government of God. Butler calls the 'course of Nature' a government, merely on the ground that it induces precautions to avoid pain. But these precautions have nothing moral in them; they may be used for criminal ends. Guy Fawkes most faithfully obeyed the laws of nature, when he placed his barrels of gunpowder so as to ensure the blowing up of Parliament, while he arranged for firing them in safety to himself. It is the object of a Law proper to prevent men from injuring one another; the uniformity of nature lends itself equally to good and to evil conduct.

The word 'Utility' has a narrow sense opposed to Art, elegance, and refinement; and a wider sense (as in the Utility theory of Morals), comprehending the whole circle of human gratifications and well-being.

'Self' has several meanings, which have to be disentangled in ethical reasonings.

The words 'same,' 'identity,' have often been commented on. Similarity or sameness is a matter of degree, and in this consideration alone lies the ambiguity. A human being is called the same person all through life, although in many respects changed.

'Probability' is not always used in its proper meaning, namely, the expression of what is true, not in every case, but in *most*. Not unfrequently, the two sets of cases, *pro* and *con*, are called the probabilities for and against a thing. The wind blows from the east, say three days in seven, and from the west four days in seven; the proper expression then is, there is a probability of four to three in favour of west wind on a given day. To say that the probabilities are four in favour of, and three against, a west wind leads to a confounding of the probable with the improbable. A vacillation between the meanings is observable in Butler's Introduction to his Analogy. He correctly expresses the nature of probability when he speaks of there being a greater presumption upon one side of a question than upon another, and remarks that if there be the slightest preponderance, prudence requires us to act accordingly. He goes on, however, to say that, in questions of great consequence, we have to be content with probabilities even lower; that is, where there is an equal balance on both sides; nay, even to *less* than this; in other words, we are to act with the majority of cases against us, which is to believe in the *improbable*.

The play of ambiguity is seen in the remark of Aristotle—'That which is naturally good is good and pleasant to the *good* man;' an equivocation too closely resembling what occurs in Plato's argument to show that the wrong-doer, if unpunished, is more miserable, than if he were punished. 'The wrong-doer' says Plato, 'when punished suffers what is just; but all just things are honourable; therefore he suffers what is honourable. Now all honourable things are so called because they are either agreeable, or profitable, or both together. Punishment is not agreeable; it must therefore be profitable or good. Whence the wrong-doer when punished suffers what is profitable or good, &c.'

Separate meanings ascribed to separate words.—This is one of the greatest snares of language. There is a strong tendency in the mind to suppose that each word has a separate meaning, and to be misled by tautologies and alterations of phraseology. The ramifications of this tendency are numerous and subtle; they include the master fallacy of Realism, or the conversion of Abstractions into Realities.

The strong verbal associations formed with all our opinions and views make us alarmed when it is proposed to withdraw the customary phrases in favour even of such as are more suitable. Stillingfleet complained that Locke's doctrine concerning Ideas 'had almost discarded Substance out of the world.' This feeling has been manifested against all the great innovations of philosophy. Because the Cartesian doctrine of Mind and Matter, as two distinct things, is declared to be gratuitous and destitute of proof, people are shocked as if Mind were done away with. The same revulsion is experienced towards Berkeley's attempt to reconcile the contradiction of the prevailing mode of regarding Perception. Whately disposes of Hume's objection to miracles 'as contrary to the Course of Nature,' by the retort that, according to him, there is no such thing as a Course of Nature, there being nothing but ideas or impressions on the mind of the individual. The unproducible entity 'Substance' is upheld in man's minds by the force of the word.

The fallacy of the Identical Proposition is due to there being two different names for the same thing :—

> There's ne'er a villain dwelling in all Denmark,
> But he's an arrant knave.

Ferrier complains of the phrase 'Perception of Matter,' as a a duplication of words for one fact, leading people to suppose that there are two facts. So, between antecedent and consequent, in Causation, there is interposed the name 'power,' to which there is nothing corresponding ; the fact being sufficiently stated by the uniform sequence of the antecedent and its consequences.

There is a difficulty in satisfying men's minds that Resistance, Force, Inertia, Momentum, Matter, are all one fact. So with the terms Motion, Succession, Direction, Distance, Situation, Extension—which are modifications of one fundamental fact—Movement and the possibility of movement.

The giving reality to Abstractions is the error of Realism and is not as yet fully conquered. Space and Time are frequently viewed as separated from all the concrete experiences of the mind instead of being generalizations of these in certain aspects. Certain things are said to be 'out of all relation to Time,' which should mean that such things have no succession and no endurance. 'Time as the innovator,' is either an unapt metaphor, or nonsense. So, 'Truth' in the abstract is a fiction ; the reality is a number of true propositions. 'Chance' lingers in men's minds as an independent existence,

instead of an assertion of identity between certain concrete situations.

The word 'Existence' in its most abstract form refers to a supposed something attaching alike to the Object and to the Subject, over and above Quantity, Succession, and Co-existence, which are attributes common to both. The only meaning of the word is the Object *together with* the Subject; for which addition we also employ the synonymous names, Universe, Being, Absolute, Totality of Things. To *predicate* existence of matter or mind is pure tautology. 'Existence' means matter or mind, or both, as the case may be. The only use of the word is to express Object or Subject indiscriminately, there being occasions when we do not need to specify either.

The valuable distinction, struck out by Aristotle, of Potential and Actual, is made the occasion of giving reality to fictions. The potentiality has no meaning but by a reference to actuality; the power of moving means motion in given circumstances. 'Educability' means education under certain conditions. Hamilton has created a fictitious intellectual faculty under the name 'Conservative Faculty;' a pure reduplication of his 'Reproductive Faculty.' We know nothing of the conservation of thoughts, except that under certain circumstances they are recalled or reproduced.

Unsuitable phraseology and unreal questions.—Many purely artificial perplexities have arisen from applying to a subject terms incongruous to its nature. The words 'true' and 'false' are properly applicable to knowledge or affirmations respecting the order of the world; they cannot be applied to pleasures and pains except by mere metaphor. A 'false pleasure' is an incongruous jumble, like a 'loud circle' or a 'bright toothache.' Aristotle puts the question—'Is happiness praiseworthy?'—to which there is no proper answer, because there is no proper meaning.

The old puzzle respecting Motion is due to the improper use of language. Motion means 'change of place' The puzzle is brought about by insisting that the phenomenon shall be expressed as *in* a place, that it shall be either in one place or in another. If we give way to this arbitrary restriction of language, we must allow, with Hamilton and many others, that Motion can be shown to be impossible.

Allusion has already been made (p. 134) to the unsuitability of the word 'hypothesis' to express abstract notions, as the definitions of Geometry.

The application of terms of Extension and Local Position

to the mind has been the source of factitious puzzles and artificial mysteries: 'How the immaterial can be united with matter, how the unextended can apprehend extension, how the indivisible can measure the divided,—this is the mystery of mysteries to man' (Hamilton's Reid, p. 886). The answer is, no attempt should be made to express the union of mind and matter in the language that would be suitable to the union of one extended thing with another.

The most conspicuous example of an artificial difficulty created by incongruous language is the celebrated Free-will theory. The sequences of the Will consist of feelings followed by actions; they exemplify mental causes giving birth to activity, and are broadly contrasted with the physical prime movers—as water and steam —which are devoid of any mental element. There is no mystery in these peculiar sequences except the mystery of the union of mind and body, formerly remarked on (p. 127). The introduction of the idea of Freedom or Liberty into the voluntary operation is totally without relevance; and the consequence has been a seemingly insoluble problem, a mesh of inextricable contradictions,

Fallacies of Relativity.—A large class of Fallacies consist in denying or suppressing the correlatives of an admitted fact. According to Relativity, the simplest affirmation has two sides; while complicated operations may involve unobvious correlates. Thus the daily rotation of the starry sphere is either a real motion of the stars, the earth being at rest, or an apparent motion caused by the earth's rotation. Plato seems to have fallen into the confusion of supposing that both stars and earth moved concurrently, which would have the effect of making the stars to appearance stationary.

Every mode of stating the doctrine of innate ideas commits, or borders upon, a Fallacy of Relativity, provided we accept the theory of Nominalism. A general notion is the affirmation of likeness among particular notions; it, therefore, subsists only in the particulars. It cannot precede them in the evolution of the mind; it cannot arise from a source apart, and then come into their embrace. A generality not embodied in particulars is a self-contradiction unless on some form of Realism.

Kant's autonomy, or self-government of the will, is a fallacy of suppressed relative. No man is a law to himself; a law co-implicates a superior who gives the law, and an inferior who obeys it; but the same person cannot be both ruler and subject in the same department.

In Ethical questions there are examples of suppressed relatives. Thus, it is often set down as essential to the highest moral virtue, that law and obligation should embrace every act of human life, that the hand of authority should never be unfelt. Now, authority means operating by penalties, and appeals exclusively to the selfishness of men's nature. Universal obligation is universal selfishness, which is not what is intended by the supporters of the doctrine.

The view is sometimes expressed that the civil magistrate is bound to support (by public establishment) the *true* religion; which, however, can mean only what he *thinks* the true religion; and the correlative or consequence is that he is bound to establish a *false* religion, provided he believes it to be the truth. This is an offshoot of the fallacy arising from the suppression of the subject mind in affirmations. An affirmation correlates with an affirmer; a truth supposes a believer. (See Part First, p. 80).

A Fallacy of Relativity is pointed out, by Mr. Venn, in the doctrine of Fatalism; a doctrine implying that events, depending upon human agency, will yet be equally brought to pass whether men try to oppose, or try to forward them. (Logic of Chance, p. 366).

The doctrine of Relativity is carried to a fallacious pitch, when applied to prove that there must be something absolute, because the Relative must suppose the non-Relative. If there be Relation, it is said, there must be something Un-related, or above all relation. But Relation cannot, in this way, be brought round on itself, except by a verbal juggle. Relation means that every conscious state has a correlative state; which brings us at last to a *couple* (the subject-mind, and the object or extended world). This is the final end of all possible cognition. We may view the two facts separately or together; and we may call the conjunct view an Absolute (as Ferrier does), but this adds nothing to our knowledge. A self-contradiction is committed by inferring from '*everything* is relative,' that 'something is non-relative.'

Fallacies of Relativity often arise in the hyperboles of Rhetoric. In order to reconcile to their lot the more humble class of manual labourers, the rhetorician proclaims the dignity of *all* labour, without being conscious that if all labour is dignified, none is; dignity supposes inferior grades; a mountain height is abolished if all the surrounding plains are raised to the level of its highest peak. So, in spurring men to industry and perseverance, examples of distinguished success

are held up for universal imitation; while, in fact, these cases owe their distinction to the general backwardness.

Petitio Principii.

Petitio Principii, *Petitio Quæsiti*, *arguing in a circle*, *begging the question*—are names for a fallacy always included by logicians in the List of Fallacies. To assume somewhere in the premises the very point to be proved is frequent in dealing with ultimate truths. The attempts to prove causation or the uniformity of nature usually take it for granted in some form or other. The inductive syllogism is a *petitio principii*. As another instance, suppose, on the one hand, the continuity of motion were given as the proof of Persistence of Force, and on the other hand, the Persistence of Force given as the proof of the continuity of motion, the argument would revolve in a circle.

A chemical writer (Gmelin) assigns as the cause of chemical decomposition by superadded bodies leading to new compounds, that the forces tending towards the new compounds are *stronger* than those maintaining the old.

Hamilton remarks that Plato, in Phædon, demonstrates the immortality of the soul, from its simplicity, and in the Republic, demonstrates the simplicity from the immortality.

Ignoratio Elenchi.

Ignoratio Elenchi, *shifting the ground*, or answering to the wrong point, is committed in many controversies. An example is furnished in the controversy relating to a Moral Sense. The opponents of the doctrine urge as an argument against a primitive or intuitive moral standard, that different nations differ widely in their notions of what is right and wrong. The reply is, that although they differ in the substance of the moral code, they agree in holding *some things* to be right and morally obligatory. This, however, is shifting the ground. The reason for appealing to an implanted sense of Right was to obtain for certain moral precepts a higher authority than human convention could give. It was not to prove us endowed with a sense that something or other is a moral obligation, but to establish the obligation of certain assigned rules (the morality of our own time)

In books on Practical Ethics, there is usually a chapter on 'Our duties to ourselves.' Like the autonomy of the Will, this is a Fallacy of Relativity, being a contradiction of the very idea of duty, which implies a superior authority. The diffi-

culty is met by shifting the ground; the allegation being that the care of our person and our interests is a duty to society and to God.

The 'Fallacia accidentis' and the 'a dicto secundum quid ad dictum simpliciter' might be brought under 'shifting the ground.' The meaning of a term is changed in its application; 'water quenches thirst,' does not mean '*boiling* water.' So, the pleasures of duty are not pleasures attaching to it as duty, or as self-sacrifice, they are incidental consequences of the situation, through the reciprocal conduct of the other party.

False Analogies.

The irrelevant comparison, or unsuitable analogy, is a usual form of confused and erroneous thinking, especially in the older philosophy. It abounds in Plato (see especially Timæus) and is not unfrequent in Aristotle; it is also prevalent in Bacon's attempts at scientific investigation.

A familiar but highly illustrative example is the comparison of the history of a nation to the life of man, in respect of birth, growth, maturity, and inevitable decay. The comparison is irrelevant; the likeness palpably fails in the most important points. A nation's losses are repaired; the physical failure of a human being is irreparable.

The reply to all such comparisons is to indicate the failure of identity. They are false minor propositions; and the falsehood is exposed by pointing out the dissimilarity of the subject with the subject of the major. They are of the same nature as a pleading in law where the relevance is unsound. The remedy is found in hostile criticism.

CHAPTER V.

LOGICAL FALLACIES.

There may be advantage in providing a supplemental collection of examples of Logical Fallacies properly so called, that is, violations of the prescribed Logical rules and methods; it being fully understood that the exemplification of the rules themselves, in the regular exposition, unavoidably affords instances of their neglect or failure.

The proper arrangement of such an additional collection (unless made promiscuous to test the ingenuity of the student) is the arrangement of the general subject. Following the order—Deduction, Induction, Definition—we should commence with Deductive or Syllogistic Fallacies.

Since, however, a separate department, preparatory to the Syllogism, is made up of Equivalent Forms, called also Immediate Inference, and since mistakes may be committed in this department (some of them the proper sources of syllogistic fallacies), the first clsss of Fallacies should be Fallacies of EQUIVALENCE, or of IMMEDIATE INFERENCE. The chief heads where fallacies occur are the *Opposition of Propositions*, and *Conversion*.

The acutest minds have been snared by confounding the Contrary with the Contradictory, of Propositions. 'The reverse of wrong is right' should be 'The reverse of wrong contains something that is either right or indifferent.' 'There are objections against a *vacuum;* but one of them must be true:' the guarded statement is, 'if there be not a universal plenum, there must be some unoccupied space, or vacuum'

The chief fallacy of Conversion is Simple Conversion of A; 'all the geometrical axioms are self-evident; all self-evident truths are axioms.' The connection of this mistake with the usual fallacies of syllogism, was sufficiently pointed out.

The proper DEDUCTIVE FALLACIES are errors against the syllogistic forms and canons. They are mainly resumed in Undistributed Middle and Illicit Process, which again usually involve the simple conversion of A. But for the snare of language that leads to this inadvertence, a fallacy of syllogism would be comparatively rare.

The INDUCTIVE FALLACIES include the most frequent and the gravest of logical mistakes. Their exemplification would naturally follow the expository order of the subject of Induction. We might commence with erroneous views of the nature of Cause, such as the suppression of important conditions and collocations. We might also connect with this part of the subject the error of assigning more causes than a phenomenon needs. It is involved in the very idea of cause, that the effect is in exact accordance with the cause; hence, the proof that more causes were operative than the effect needed, defeats itself. If we have an adequate cause for slavery, or for the subjection of castes, or classes, in the mere love of domination on the part of the stronger, the explanation that the state of society demands such an arrangement is of no value. This is the error called 'proving too much.'

Next are the Fallacies from insufficient employment or neglect of the Methods of Elimination. Under Agreement falls the mistake (exemplified in Medicine) of confounding induction with multiplication of instances, without variation of circumstances. Mr. Mill's Fallacies of non-observation likewise sin against the methods. An induction is not complete till all the instances, or representatives of them all, have been examined. Paley, in affirming 'that happiness is equally distributed through all classes of the community,' must have left out of account the larger part of the facts.

The assertion that 'Species are never transmuted,' even although not disproved by positive instances to the contrary, would require an examination of facts far beyond what has ever been made. Leibnitz generalized his 'Law of Continuity' from a few unquestionable instances, without verifying it through all nature.

The fallacious inferences named 'Non causa pro causa,' 'Post hoc ergo propter hoc,' are fallacies of the inductive methods. Some circumstance coupled with an effect is held to be its cause, without due elimination. Thus, the luxury in the Roman empire is said to have been the cause of its downfall; commercial restrictions, in spite of which trade has prospered, are made the cause of prosperity.

The fallacy of not recognizing Plurality of Causes will be apparent from what was advanced on that subject. So, the fallacy of trusting to the Inductive Methods in Intermixture of Effects was necessarily involved in the reasons given for coupling Deduction with Induction.

Under Secondary Laws, there is obviously involved the fallacy of applying a general law to a concrete instance, or to an intermediate law, without the due modifications; as if we were to infer from the Law of Gravity that all the planets are falling direct to the sun.

Fallacies of Explanation were expressly exemplified. A non-compliance with the logical conditions of Hypotheses would yield fallacies on that subject.

FALLACIES OF DEFINITION would, in the first place, express the use of ill-defined terms. Again, the failure to satisfy the methods and rules of Classification is a sin against Logic. We need but instance the wide prevalence of the error of *Cross-divisions*. Bacon is prolific of divisions and sub-divisions, which are never logical. His four classes of Idola are not mutually exclusive; his Prerogative Instances will be afterwards remarked on.

APPENDIX.

F.—ANALYSIS AND SYNTHESIS.

The common idea in the correlative couple—Analysis and Synthesis—is difficult to express adequately, owing to the variety of its applications. Chemical Analysis, Mathematical Analysis, Logical Analysis, with the corresponding Syntheses, have a basis of agreement but with points of difference.

The general idea of Analysis is separation; of Synthesis, composition or combination. Yet the contrast does not altogether correspond to the distinction of Abstract and Concrete. Analysis is Abstraction, but Synthesis is not the negative or the absence of Abstraction; it is not the *un-abstracted* Concrete. While the scientific man is, by the law of his being, an analyst, the poet or artist, who does not analyze but combines, is not a synthesist. Synthesis in contrast with analysis, is combining *after* analyzing; it is using the results of analysis with a view to construction.

The simplest exemplification of the two correlated processes is seen in CHEMICAL Analysis. The Chemist operates upon an unknown mixture or combination of material bodies, as a newly discovered mineral, a water, a strange product from a furnace, the stomach of a poisoned man. He separates and identifies the various ingredients of the compound. Given the water of a mineral spa, he states exactly what saline bodies, and gases are dissolved in it, and what is the amount of each.

The obverse Synthesis would consist in making up the given compound by means of the several elements in their proper proportions. Thus, having ascertained the precise constituents of a mineral water, it is then possible to form the water artificially. If the artificial water is exactly identical with the natural water, both the analysis and the synthesis are successful and complete. It is by the analysis, however, that the synthesis has been possible. The analysis is the foundation of a new means of production; it enables us not merely to imitate and rival the spontaneous products of nature, but also, if need

be, to vary those products on a definite plan or purpose. We may introduce beneficial variations into the syntheses of mineral waters. So, having analyzed some crude substance medicinally valuable, we may artificially compound it, first, literally (which proves the sufficiency of the analysis), and next with improved adaptations for the end.

The most notable application of Chemical synthesis is to the formation of *organic* compounds in the laboratory. By a foregone analysis, the chemist has discovered the constituent elements of these compounds, and the peculiarities of their union; he then uses his knowledge to re-produce by laboratory processes what has been produced in the course of living growth. In this way, urea, acetic acid, and many other organic products have been obtained by laboratory synthesis. Such synthetic efforts are the trophies of analysis.

Our next example may be termed LOGICAL Analysis; it is the ordinary Scientific Analysis, the peculiar case of Mathematics being reserved. Here, Analysis is substantially identical with generalization, whether of the notion or of the proposition. What Synthesis is will appear presently.

The processes of assimilating, identifying, classing, generalizing, abstracting, defining, are the various sides, aspects or stages, of one fundamental operation. Now Analysis is merely a farther aspect, another side, of the same proteus. To identify, classify, and abstract, is to separate or analyse, so far as the case admits; the separation being no longer actual, as in Chemistry, but mental or ideal. To identify and classify transparent bodies, is to make abstractive separation, or analysis, of the property called transparency; or to view its functions, powers, or agencies alone and apart from all the other powers possessed by the individual transparent bodies. Water is liquid, but this aspect is disregarded; diamond has extraordinary refractive power but no notice is taken of it; the two substances are studied merely in their agreement in what we call transparency.

Now the investigation of nature turns exclusively on this abstractive separation. Bodies are constituted with a cluster of powers or properties inseparably combinated, yet each pursuing its independent course without any disturbance from the others. Water, as transparent, has a power exactly identical with diamond and rock crystal, as transparent; the other peculiarities wherein the two bodies stand widely contrasted have no relevance, exercise no interference, as regards the transparency. Hence, the mind, having very limited powers

of attention, and being easily impeded and thwarted by distracting circumstances, finds the advantage of neglecting all allied properties, and concentrating its powers on the one subject of study at the time.

Thus, Abstraction and Analysis, if not identical, are the same fact viewed with a slight difference. Abstraction means separately viewing one point of agreement, and leaving all other accompaniments in the shade; the transparency is studied by itself, the specific gravity and all other incorporated properties being left out of sight. Analysis means the very same thing; only, proceeding a little farther, it supposes that *every one* of the powers of a given concrete, as water, may be abstracted by turns,—transparency, liquidity, specific gravity; so that water as a whole may be analyzed, or separated (mentally) into a number of different powers, whose enumeration is a full account of the agency of water.

The farther we push abstraction and generalization, the farther we push Analysis. When, after generalizing all mechanical movements, and forming an abstract idea, or analytic separation of molar or mechanical force, we proceed to identify mechanical momentum with molecular forces, we make a new analysis; we separate the property of force from its exclusive connexion with the movements of masses, and view it as the movement of matter, whether in larger or in smaller aggregates.

It is now requisite to assign a correlative meaning of Synthesis. As Analysis is the ideal separation and separate exhibition of all the functions of a concrete thing, as water, iron, blood, Synthesis is the re-statement of the whole in their aggregate. Its efficacy would be shown in supposing a new aggregate, as a liquid diamond, a metal with all the properties of lead except its corrosion. It would also be exemplified in the act of communicating, by description, the knowledge of a mineral, apart from a concrete specimen.

Another step is inevitable. As these abstractive properties, or notions, are what enter into the *inductive generalizations* of nature, each inductive law being two or more coupled together, Analysis becomes applied to Inductive discovery. There can be no wide induction without a correspondingly wide generalization of at least two notions, that is, without an equivalent analytic separation. The summit of generalization, in the notions Quantity, Inertia, Gravity, Persistence, is the summit of Analysis. The highest generalities of Mind are attained through the most thorough Analysis of Mind.

The employment of Analysis to signify *Induction* appears in Aristotle, and pervades the logicians after him. (See Mansel's Aldrich, App. G., Hamilton's Logic, II., 2). By an easy transition, Synthesis would be applied to *Deduction*. The deductive operation of following out the law of gravity to lunar perturbations, to the tides, to precession, &c., would be called synthetical, as reuniting abstract elements into new combinations. Having mastered the laws of central force, and the composition of forces, Newton deduced or inferred the orbits of bodies governed by other forces than gravity.

Synthesis, however, scarcely applies to *simple* Deduction, the following out an induction to a new case, as when we infer the death of the reigning pope from the mortality of the men that have died. There is no element of combination in such cases, there is but the filling up of the Induction, which is only *formally* complete so long as any particulars are still outstanding. The synthetic operation is best realized by the *complex* deductions, or the union of several deductive laws to a composite or concrete case—a secondary law.

There is nothing gained by using the terms Analysis and Synthesis to the Inductive and Deductive processes respectively. We may show in what way the application is proper or admissible, and that is all.

The use of the Syllogism may be expressed as analyzing or separating, out of regard to our mental infirmity, the three parts of a step of reasoning, so that they may be studied in separation. The premises, instead of being confused together, can be looked at apart, and each judged on its merits in its isolated condition. This is an advantage belonging to Method, or Discovery. Wherever a separation of this kind can take place, a great relief is given to the understanding, with a corresponding enlargement of its powers.

An accountant separates his columns of debit and of credit, and classifies under different heads payments that relate to different subjects and follow different rules.

Grammatical Analysis may be followed by Grammatical Synthesis, as in constructing sentences upon new types suggested by putting together the component elements in various ways.

Criticism is a species of analysis; and the composition of an Oration or a Poem, by the guidance of critical and rhetorical rules, is a strictly synthetic operation; the previous analysis is the foundation of the method. Composition, without any rules, is not synthesis.

It is a weakness of the unscientific man to suppose that a concrete thing, as, for example, a political institution, can be viewed only as a whole—that its operations are an indivisible totality. Thus, the obtaining of justice by the procedure in a court of law is through a series of steps and processes—raising the action, appearing by counsel, summoning a jury, and so on. The effect of the whole being good, the un-analyzing mind distributes the merit equally over all the parts, and is shocked when a doubt is raised as to the utility of any one constituent, as, for example, the jury.

To advert finally, to the special instance of Mathematical Analysis and Synthesis. A new step in geometry may be taken either by analysis or by synthesis. The various Geometrical properties are said to have been first discovered, by analysis, while in exposition they are in the form of synthesis; which is not strictly the fact; we may proceed from the known to the unknown in both ways; discovering new properties by synthesis no less than by analysis.

Let us take Synthesis first, as suiting the case of a science whose onward march is by the way of Deduction. Let us assume that a certain proposition has been arrived at, no matter how, say, 'Parallelograms on the same base, and between the same parallels, are equal.' Now any one considering this proposition might readily see, that the axiom of mediate equality applied to it, would show that the same thing might be predicated of *equal bases;* such an inference would be an effort of pure *deduction*, or the skilful combining of two already established propositions to yield a new third proposition. So, by a repetition of the same apposite union of truths possessed, one might also infer that '*Triangles* on the same base, or on equal bases, and between the same parallels, are equal.' By farther combinations, the reasoner might go on to deduce or infer the 47th, and so forth. All which is a purely synthetic operation; and geometrical truths may be evolved to any extent in this way. Corollaries are usually deductive inferences, of short leap, from the main proposition. The operation is seldom one of simple deduction, there is usually a certain concurrence of two or more propositions to the new result; and the mental effort lies in bringing these together. Geometrical synthesis and deduction are thus the same thing.

What then is Geometrical Analysis? Is it Induction? We are told that it proceeds from the unknown to the known. If one were to suspect or surmise (without being sure) that the

square of the hypothenuse of a triangle is equal to the sum of the squares of the sides, and assuming it, were to endeavour to connect it by a thread of geometrical reasoning with the established propositions of geometry, the operation would be called analytic or regressive, as compared with the synthetic or progressive course above described. Yet in reality, the mental operation is substantially the same in both; the two differ only in superficial appearance, like the enquiry from cause to effect, and from effect to cause. Assuming the truth of the surmise first, we have to consider what prior propositions would be requisite to support it; and, again, what other propositions would support these; until we come at last upon admitted theorems. The real operation at each step is a deductive one; we feign a proposition and try its consequences; if these coincide with the case, such proposition or propositions are what we need; and if they are found among the true propositions of geometry, we have made good our point; we have proved our surmise, and put it in the train of geometrical deductions.

The facilities for this inverted deduction are so greatly multiplied by Algebra as to give to the algebraic processes the designation 'analytical' by pre-eminence. In an Algebraic equation, we work backward from the known to the unknown; yet it is by a series of properly deductive operations—the application of axioms and theorems already established. Algebraic Geometry is called 'Analytical;' the more recondite processes of Algebra are called the Higher Analysis.

Thus, while Synthesis has throughout a reference to the deductive and combining processes of science, Analysis relates to generalization or induction, everywhere except in Mathematics, in which it is merely the mode of deductive synthesis adapted to the solution of special problems. The geometer, when he has no special end in view, evolves new propositions by direct or progressive synthesis; when he has a problem to work out, he confines his deductions to those that lie in the approaches to the desired solution. The course of discovery in a Deductive science can be only Deductive; it consists in following out generalities in hand to new applications; usually by combining several in one application. The art, the labour, lies in the union of several propositions to a result. The operation must be tentative; it cannot be foretold; yet it is amenable to a certain general method, which practice instils, and which is not altogether beyond the reach of precept.

G.—GROWTH OF THE LOGIC OF INDUCTION.

Previous to Mr. Mill, the principal contributors to the Logic of Induction were Bacon, Newton, Herschel, and Whewell.

BACON.—The essential part of the service rendered by Bacon to Science was his protest in favour of basing generalities on a patient collection and accurate comparison of facts. It was too much the custom, he complained, to 'just glance at experiments and particulars in passing;' in place of this, he proposed to 'dwell duly and orderly among them.' With the whole force of his eloquence he discouraged flighty speculation and rash conjecture, and urged that generalities must be founded upon a wide comparison of particulars.

Following up his emphatic enunciation that men must have done with rash speculations and rashly abstracted notions, if they desire to make progress in their knowledge of Nature, he devised modes of elucidating truth by the comparison of instances on a methodical plan. He directs the arrangement of facts in three different tables. The first table is to contain instances agreeing in the presence of the phenomenon to be investigated; this he calls a Table of Essence and Presence (*Tabula Essentiae et Praesentiae*). The second table is to contain instances wanting in the phenomenon, but otherwise allied to the instances where the phenomenon occurs, each instance corresponding as far as possible to some one instance in the first table; this he calls the Table of Deviation, or of Absence in Allied Instances (*Tabula Declinationis*, sive *Absentiae in Proximo*). The third table contains the phenomenon in different degrees, and is called the Table of Degrees or Table of Comparison (*Tabula Graduum*, sive *Tabula Comparitiva*). The constitution of the three Tables is exemplified upon an enquiry into the phenomenon of Heat; for the prosecution of which are assembled no less than 27 instances agreeing in the presence of heat, 32 allied instances agreeing in its absence, and 41 instances of heat manifested in different degrees.

The three Tables seem designed for the convenient application of the three leading methods of Inductive elimination—Agreement, Difference, and Concomitant Variations; but we must not suppose that Bacon realized anything like the precision of those methods. He did not conceive the idea of choosing his instances so that they should differ in every point but the phenomenon under investigation, agreeing only in that—the fundamental idea of the method of Agreement. Nor did he conceive the idea of the decisive method of Difference, the

choice of two instances agreeing in every point save the given phenomenon. Having collected his Tables of Instances, he went to work by excluding according to certain canons the irrelevant instances, then making a hypothesis or guess at the truth, and finally verifying this by farther enquiry.

Bacon takes especial credit for his process of Exclusion or Rejection. He contrasts it with the popular method of proceeding by Simple Enumeration, that is, by counting only the favourable instances, overlooking the unfavourable; and he claims to be the first to make it prominent. The problem of Induction being to 'find such a quality as is always present or absent with the given quality, and always increases or decreases with it,' 'the first work of true induction is the rejection or exclusion of the several qualities which are not found in some instance where the given quality is present, or are found in some instance where the given quality is absent, or are found to increase in some instance where the given quality decreases, or to decrease when the given quality increases.'

It will be observed that this process of exclusion, although a great advance upon generalizing without regard to contradictory instances, is very rudimentary. Bacon does not distinguish between laws of simple Co-existence and laws of Causation. The first of his principles of Rejection is suited only to the establishment of co-existences, and amounts to this, that we are not to declare two qualities universally concomitant, if in certain instances we find one absent when the other is present. His other principle of rejection is the reverse of the method of Concomitant variations, a disproving of causal connexion on account of independent variation; and applies to causation alone.

As to the modes of *certifying* the hypothesis allowed after this process of collecting and sifting instances—the Logic of Proof, Bacon has left us but a fragment. Of his *nine* divisions of aids to Induction, he completed only the first, *Prerogative Instances*. Under this head, he dictates a farther enquiry into particulars, and dwells upon instances of special value to the inquirer, calling them Prerogative from that circumstance. To call this division of his subject an aid to induction is misleading; we expect to find an account of instances particularly suitable for founding inductions upon, and find instead illustrations of various maxims applicable to Definition, Observation, and even Experiment, as well as some specially adapted for Inductive Elimination.

It is among the Prerogative Instances, if anywhere, that we are to look whether Bacon had conceived any practical device for bringing the process of Exclusion or Elimination to a positive result, as is done in the modern methods of Agreement and Difference. Under the heading of *Solitary* Instances, we do find a crude approach to the selection of instances implied in these methods. Solitary Instances are either instances that exhibit a phenomenon without any of its usual accompaniments, as colour produced by the passage of light through a prism; or instances agreeing in everything except some particular phenomenon, as different colours in the same piece of marble. He says in a vague way that such instances shorten very much the process of Exclusion. They contain really all that is demanded for the methods of Agreement and Difference. Yet in Bacon's hands they are comparatively useless, and, as part of his method, could not even furnish a suggestion for more perfect contrivances. The reasons are to be found in his vague conception of the problem of Induction. His methods of Exclusion are of avail only for problems of Cause and Effect; they are superfluous for problems of simple concomitance, a single instance of disunion being sufficient to disprove such a connexion; yet he speaks throughout as if his elaborate comparison of instances were designed only to prove two properties co-existent. To this confusion he was inevitably led by the subjects he proposed to investigate. He seems to have thought principally of investigating abstract qualities of bodies, such as density, weight, colour, volatility, porosity, heat; his purpose being to establish their Form, by which he seems to have vaguely understood something invariably present with these qualities and endowing them with their peculiar nature. Such an investigation gave ample scope for numerous assemblages of instances; but the methods of sound knowledge were not likely to be perfected in a region that can be approached only by hypothesis.

Under *Migratory* Instances, keeping still in view the same class of subjects, he recommends attention to cases where qualities are produced in bodies; giving, as examples the production of whiteness by pounding glass and by agitating water into froth. From this we gather that he was sensible in a measure of the advantage of studying the introduction of a cause into known circumstances, although in his narrow field of investigation it could lead to no result.

In these two first instances we see how far he anticipated the Methods of Agreement and of Difference. Few of the other

twenty-five instances bear strictly on the Inductive Process. With *Migratory* Instances, he compares *Instances of Companionship or Enmity*, such as the universal concurrence of heat with flame, and the universal absence of consistency in air; just as when a change is produced, we must seek the cause in some added influence, so when a quality is always present in a substance, we must seek the cause in some property of that substance. In *Striking* or *Shining* Instances, and *Clandestine* Instances, he urges the importance of the two extremes in a variable phenomenon. His seventh and eighth Instances, *Singular Instances* (as the magnet among stones, quicksilver among metals), and *Deviating Instances* (individual monstrosities), are important for a like reason; their novelty sharpens investigation. His twelfth case, *Instances of Ultimity or Limit*, is of the same nature. The five last go together; the stimulating efficacy ascribed to them is a favourite topic with Bacon, and is the real characteristic of several other Instances. *Instances of Alliance or Union* and *Instances of Divorce*, the thirteenth and fourteenth, form a natural couple. The one constitute instances reconciling apparent contradictions; the heat of the Sun cherishes, the heat of Fire destroys; a conciliatory instance is found in the growth of grapes in a house heated by fire. The second constitute instances disproving an alleged universal connection; it is asserted that Heat, Brightness, Rarity, Mobility are always found together; we point to *air*, which is rare and mobile but neither hot nor bright.

In exemplifying *Instances Conformable* or *of Analogy*, he breaks clean away from Inductive caution; he gives as analogous cases the gums of trees and most rock gems, and refers the splendour and clearness of both products to the same cause, fine and delicate filtering. Such fancies show how little Bacon was removed from the rash speculation he condemned in the works of his predecessors.

His fourteenth case, the famous *Instantia Crucis* (*Fingerpost* Instance), is mentioned in the Chapter on Hypotheses, § 7, (p. 135), and is there placed in its true light as an instance decisive of rival hypotheses. Such instances are otherwise called *Decisive and Judicial* or *Oracular and Commanding*.

These are all the instances that have a direct bearing on Induction. Of the remainder, two are of importance for Definition, the fifth and the ninth, *Constitutive* Instances, and *Bordering* Instances. *Constitutive* instances give the constituents of a complex notion; *Bordering* instances make the baffling transition border between two classes.

Five instances are classed together as *Instances of the Lamp, or of First Information;* and relate to Observation. Under *Instances of the Door or Gate* he comments on artificial aids to the Senses—the Microscope, the Telescope, and measuring rods. By *Summoning* or *Evoking* Instances, he means indications of things not directly accessible to observation; such are the pulse and the urine, as symptoms of the condition of the human body. *Instances of the Road,* otherwise called *Travelling* and *Articulate* Instances, display stages of growth and of other gradual changes :—the study of these is strongly recommended. *Supplementary Instances* or *Instances of Refuge* are said to supply us with information when the senses entirely fail us; when we cannot remove an agent altogether we may vary its influence, and when a phenomenon defies observation we may study analogous phenomena. *Dissecting* or *Awakening* Instances are such as great effects produced by small causes; they appeal to our wonder, and stimulate enquiry.

The seven concluding instances embody advice on the practical conduct of investigations. The four first of the seven instruct us how to attain precision by definite determination and measurement (*Mathematical* or *Measuring Instances*); the three last how to economize our resouces (*Propitious* or *Benevolent Instances*). The Mathematical Instances are *Instances of the Rod or Rule,* otherwise called *of Range* or *of Limitation* (where measurement of *Space* is required); *Instances of the Course* (measurement of *Time*); *Instances of Quantity,* or *Doses of Nature* (where attention is called to the *quantity* of an agent); and *Instances of Strife* or *Predominance,* under which title he gives a confused enumeration of various 'Motions,' or tendencies to motion, and represents the movements of bodies as determined by the victory of one or other of these conflicting tendencies—for example, when water runs out of a crack, the motion of *Continuity* is overcome by the motion of *Greater Congregation* (the tendency of bodies to the ground). Nothing could be more fanciful and illogical than this enumeration of 'Motions.' The *Propitious* Instances are—*Intimating* Instances, which point out what is most useful to mankind; *Polychrest Instances* or *Instances of General Use,* (contrivances useful for a variety of purposes, as various modes of excluding air from bodies to prevent decomposition); finally, *Instances of Magic,* the use of small causes to produce great effects.

We have given no account of the tenth division, *Instances of Power,* otherwise *Instances of the Wit* or *Hands of Man.* It is partly identical with awakening Instances: we have singled

it out here as containing a homily against being led away by admiration of skilful contrivances from better ways of accomplishing the same end.

In concluding this brief account of the Baconian method we may reiterate that the merit of Bacon lay neither in the machinery he provided nor in the example he set, but in the grand impulse he gave to the study of facts.

NEWTON. Newton cannot be said, any more than Bacon, to have made a direct contribution to the methods either of Discovery or of Proof; but he set an example of rigorously cautious enquiry that did more than all the precepts of Bacon to raise the standard of Proof, and to purify science of fanciful hypotheses. He even went to an extreme and was over-rigorous in his requirements of proof; such was his dislike to making hypotheses (in the sense of assuming causes not known to exist), that he wished to banish them from science altogether.

The Rules of Philosophizing (*Regulæ Philosophandi*) prefixed to his Principia were long quoted as authoritative. Although worded with an express view to the establishment of Gravitation, they are necessarily applicable to other inductive generalizations.

The Frst rule is twofold, and may be thus explicated. (1) "Only real causes" (*veræ causæ*, actually existing causes) "are to be admitted in explanation of phenomena." We have stated the limits to this under Hypotheses (p. 131). (2) "No more causes are to be admitted than such as suffice to explain the phenomena." This is an echo of the maxim known as 'Occam's razor' ('Entia non sunt multiplicanda præter necessitatem'), and means that when one cause is proved to be present in sufficient amount for the effect, we are not at liberty to suppose the presence of other causes. From a few words of explanation affixed to the rule, we should gather that he meant also to suggest that there was a presumption in favour of an explanation accounting for the phenomena by the fewest agencies—a special pleading for his theory of gravitation: 'Nature does nothing in vain, and a thing is done in vain by several agents when it can be done by a smaller number.'

The Second rule is—"In as far as possible, the same causes are to be assigned for the same kind of natural effects." For example, respiration in man and in beasts; the fall of stones in Europe and in America. An aspect of the Uniformity of Nature designed to favour his view of Solar attraction as the

same kind of effect with the attraction of the Earth for the Moon or for terrestrial bodies.

The Third—"Qualities of bodies that can neither be increased nor diminished in intensity, and that obtain in all bodies accessible to experiment, must be considered qualities of all bodies whatsoever." Another aspect of the Uniformity of Nature, also specially adapted to his extension of Gravity to the heavenly bodies.

The Fourth—'In philosophical experiment, propositions collected from phenomena by induction, are to be held, notwithstanding contrary hypotheses, as either exactly or approximately true, until other phenomena occur whereby they are either rendered more exact or are proved liable to exceptions.' This is indirectly aimed at the Cartesian explanation of the celestial movements by Vortices, the word hypothesis being used in an opprobrious sense, as involving an element of fancy operating upon imperfectly known materials. The rule may be held to imply that the test of a theory is its accordance with facts, which is not altogether correct.

HERSCHEL. Sir John Herschel devotes a considerable portion of his *Discourse on the Study of Natural Philosophy* to an account of 'the principles on which Physical Science relies for its successful prosecution, and the rules by which a systematic examination of Nature should be conducted, with illustrations of their influence as exemplified in the history of its progress.' His introductory chapters on this head reiterate with greater clearness the admonitions of Bacon; enforcing recourse to experience as the sole fountain of knowledge, illustrating the dangers of prejudice, and urging the importance of recording observations with numerical precision. Farther, he dwells upon the value of Classification and Nomenclature; although he suggests no leading principles for either process. In these preliminary remarks we recognize the sagacity of the practised experimenter; but it is when he comes to analyze what is involved in the notion of Cause, and to state his rules of philosophizing, that we become fully aware of the advance made in the investigation of Nature since Bacon and Newton, and of the advantage possessed by the expounder of scientific method in having a large body of successful observations and experiments to generalize from.

From the characters implied in the connexion between cause and effect, he derives *nine* 'propositions readily applicable to particular cases, or rules of philosophizing.' Four of them, the second, seventh, eighth, and ninth, are the four

Experimental Methods; which are stated with sufficient precision, although not exalted into the prominence given them by Mr. Mill as the sufficing and only methods of Proof. By Herschel in fact, the four rules are regarded solely as aids to Discovery; the idea of Proof does not seem to have crossed his mind. His other rules are more purely suited for Discovery. The first is a more precise statement of Bacon's main principle of Exclusion, the foundation of the methods of Agreement and of Difference:—'that if in our group of facts there be one in which any assigned peculiarity or attendant circumstance is wanting or opposite, such peculiarity cannot be the cause we seek.' The third is 'we are not to deny the existence of a cause in favour of which we have a unanimous agreement of strong analogies, though it may not be apparent how such a cause can produce the effect, or even though it may be difficult to conceive its existence under the circumstances of the case':—a maxim identical with the principle of analogy, that we may sometimes infer the presence of one phenomenon from the presence of another, although no causal connection has been established between them. As an example he states that though we do not know how heat can produce light, we yet conclude that the sun is intensely hot because it is vividly luminous. The fourth rule is that 'contrary or opposing facts are equally instructive for the discovery of causes with favourable ones.' The fifth recommends the tabulation of facts 'in the order of intensity in which some peculiar quality subsists,'—perhaps the most valuable art of Discovery. To this precept Herschel very properly appends that the value of the device may be frustrated by the interference of counteracting or modifying causes. The sixth rule reminds the enquirer 'that such counteracting or modifying causes may subsist unperceived,' and urges attention to them as a means of explaining exceptions.

In some general remarks following the enunications of his rules, he illustrates the necessity of combining Deduction with Induction in complicated enquiries, and explains the nature of Empirical Laws, glancing at the fact that they are limited in their application to new cases, without stating more precisely what their limits are.

The concluding chapter treats 'of the higher degrees of Inductive Generalization, and of the formation and verification of theories.' He insists that the assumed agents must be *veræ causæ*, 'such as we have good inductive grounds to believe do exist in nature.' The value and the test of a hypo-

thesis he places in its accordance with the facts, and its enabling us 'to predict facts before trial.'

WHEWELL. The scheme of the late Dr. Whewell's *Novum Organum Renovatum* commends itself as strikingly thorough and exhaustive. It professes to be 'a revision and improvement of the methods by which Science must rise and grow,' founded upon a comprehensive History of Scientific Discovery and a History of Scientific Ideas. Now, theoretically, there could be no more perfect way of elaborating a body of maxims for the aid of the discoverer, than to pass in review, chronologically or otherwise, the great physical discoveries that have been made, and to study the essentials of the process in each case.

The distinguishing feature of Whewell's scientific writings is his persistent driving at an antithesis that he conceives to be fundamental, between Ideas or Conceptions and Facts. This antithesis is the shaping principle of his system and meets us at every point. It regulates the division of his history into two parts: the *History of Scientific Ideas* tracing the gradual development of the so-called ideas, such as Cause Affinity, Life, that form the subject-matter of various departments of science; and the *History of Scientific Discovery*, illustrating how by the instrumentality of Ideas (the highest generalities), and of Conceptions (the lower generalities), the particular facts of Nature are united and bound together. The same antithesis divides scientific method into two processes. Generalization consisting not in evolving notions from a comparison of facts, but in superinducing upon facts conceptions supplied by the mind. There are two requisites to satisfy before this operation can be perfected, namely, that the Conceptions be clear and distinct, and that they be 'appropriate' to the Facts, capable of being 'applied to them so as to produce an exact and universal accordance:' whence there are two scientific processes, *the Explication of Conceptions* and the *Colligation of Facts.*

The grand problem of Science is to superinduce Ideas or Conceptions upon Facts. The business of the discoverer after familiarizing himself with facts, is to compare them with conception after conception, in the view of finding out after a longer or shorter process of trial and rejection, what conception is exactly 'appropriate' to the facts under his consideration. When the investigator has at length, by a happy guess, hit upon the appropriate conception, he is said to 'colligate' the facts, to 'bind them into a unity.' No distinction is

drawn in this operation between the generalization of Notions and the generalization of Propositions ; the difference between them is merged in the one grand purpose of procuring for facts clear and appropriate conceptions.

It is difficult to understand what he supposes to have been the origin of the conceptions thus superinduced upon facts. He speaks of them as being struck out in the gradual march of Science by the discussions and reflections of successive thinkers, a view not inconsistent with their derivation from the comparison of particulars and the gradual evolution of deep and pervading agreements. But he says also that they are supplied by the mind, while facts are supplied by sense; and the language he holds regarding the suiting of facts with their 'appropriate' conceptions, is consistent only with the assumption that the mind is a repository of conceptions accumulated there independently of the experience of particulars.

By this initial severance of generalities from the particulars they repose upon, he excluded from his method definitions formed by the comparison of facts and the precise statement of common features. He rather decries the value of Definition, and allows it no place of hononr in his *Explication of Conceptions*. The meaning of a conception is, he thinks, oftener apprehended from an axiom than a definition—another instance of his total neglect of the distinction between notions and propositions.

His 'methods employed in the formation of Science,' the title of the third Book of the Novum Organon, are three in number, *Methods of Observation, Methods of obtaining clear Ideas, and Methods of Induction.* As a preliminary to Observation, he recognises an Analysis or Decomposition of Facts. Under Observation, he discusses chiefly the modes of obtaining precise measurement; he speaks also of the education of the senses, but does not attempt to lay down any definite precepts farther than recommending the study of Natural History and the practice of Experimental manipulation. His Methods of acquiring clear scientific ideas, are neither more nor less than the study of the various departments of science where the ideas occur ; the very method that would be recommended by a preceptor believing in the evolution of general notions from particulars. An aid to the acquisition of clear ideas is Discussion.

We find no trace of the three leading Experimental Methods in his Methods of Induction, nor indeed of any methods of Proof He conceived that his province was to furnish arts of Discovery, in so far as anything was of avail beyond natural

sagacity; and he seems to have thought slightingly of the efficacy of the Three Methods as a means to the attainment of new laws. His principal arts of Discovery are given under the title of 'Special Methods of Induction applicable to Quantity." The *Method of Curves* is a device for making apparent to the eye the result of observations on the concomitant variation of two phenomena. It 'consists in drawing a curve of which the observed quantities are the *Ordinates*, the quantity on which the change of these quantities depends being the *Abcissa.*' The *Method of Means* is the familiar device of eliminating the effects of a constant cause from the conjoined effects of accidental accompaniments by striking an average of several observations. The *Method of Least Squares* is a somewhat complicated supplement to the Method of Means. When more than one mean is proposed, they are each compared with the series of actual observations; the deviations from each case in the series are squared, and the mean is affirmed to be most probable, the sum of whose squares is lowest in amount. The *Method of Residues* is the method we described under that name.

Under the title of 'Methods of Induction depending on Resemblance,' he illustrates the *Law of Continuity* ('that a quantity cannot pass from one amount to another by any change of conditions, without passing through all intermediate magnitudes according to the intermediate conditions'); the *Method of Gradation*, a name given to the process of proving that things differ not in kind but in degree); and, in the *Method of Natural Classification*, enforces the importance of grouping objects according to their most important resemblances.

Perhaps the most valuable part of the Organon is the concluding Book on the *Language of Science*. Of this subject Whewell had made a special study; his aphorisms on the requisites of philosophical language contain nearly all the important points.

H.—ART OF DISCOVERY.

It was the distinction of Mr. Mill's handling of Logic to draw a clear and broad line between the Art and Science of Proof and the Art of Discovery. The main business of Logic, according to him, is the proving of propositions; only in an incidental way does it aid in suggesting them.

There is, in the laws of evidence well understood, a powerful *indirect* incitement to original discovery. A thorough

means of testing whatever is propounded for acceptance leads to the rejection of the false, and, consequently to a renewed search, ending at last in the true. For this reason alone would discovery be more rapid in the Mathematical and Physical sciences, where verification is easy, than in the Mental, Moral, and Political sciences, where the facts are wanting in the requisite precision. Kepler was not left in any doubts as to whether he had arrived at the true law of the periodic times of the planets; psychologists could not so easily satisfy themselves as to the thorough-going concomitance of mind and body.

The Arts and methods of Discovery embrace (1) the Facts, that is, Observation; and (2) the Reasonings on Facts, namely, Deduction, Induction, and Definition; which are all comprehended in the one process, *generalization.*

As regards the accumulation of Facts, there is little to be said, and that little is apparent at a glance. Facts are obtained by active search, enquiry, adventure, exploration. For some, we must travel far, and visit many countries; for others we have to lie in wait till occasions arise. For a third class, we have to institute experiments, involving contrivance and devices, and the creative ingenuity of the practical mind; all which is itself a department of discovery, the least of any amenable to rules

The arts of Observing were remarked on, in the Introduction, as being special for each department, and not a fit subject for general logic. The precautions common to all kinds of observation, in regard to accuracy and evidence, would be worthy of being recited, provided there could be given a sufficiency of illustrative instances to make the desired impression.

From the limitation of the human faculties, the highest powers of observation are not usually accompanied with high speculative force. Hence, among other consequences, a not unusual misdirection of the energies of great observers.

Passing from the region of fact, we come to the region of Generality. A number of individual observations being supposed, the next thing is to discover agreements among them—to strike out identities wherever there are points to be identified; these identities ending either in Notions or in General Principles. It may seem a work of vast labour to exhaust all the facts of the material and of the mental world; it is not a less labour, although of a different kind, to exhaust all the *identities* among the facts.

Although the main condition of success, in bringing about

identities, is a peculiar intellectual aptitude, belonging to some men in a pre-eminent degree; yet there are aids, methods, and precautions, for increasing the power. Some of these aids are suggested by intellectual psychology, others grow out of the methods unfolded in logic.

The methods growing out of the psychology of the intellectual powers are briefly these :—to possess the mind of a large store of the related facts; often to refresh the recollection of them; to come into frequent contact with subjects that seem likely to afford comparisons and analogies; not to stand too near any one set of facts so as to be overpowered by their specialities; not to be engrossed with the work of observing the facts; and in general, as to matters of great difficulty, to keep the mind free from attitudes and pursuits antagonistic to the end in view.

Newton alternately devoted himself to mathematics and to the observation and collection of facts in the various subjects of natural philosophy; and this alternation doubtless makes the perfect physical enquirer.

Frequently an identification has to be embedded in some conception apart from the facts; as Kepler's laws in numerical and geometrical statements, the law of sines, &c. In such cases, proximity to the sources of the conceptions will help to bring about the coalition. If mathematical relations, the mathematical knowledge should be kept fresh, and so with other subjects. These constructing instances alone give any meaning to Whewell's much iterated antithesis of Fact and Idea. The identification and generalization of facts often happens without any 'idea,' any central form, or representative beyond the facts themselves; there is no idea for a circle but round things, abstractedly viewed; and no idea for gravity, but gravitating bodies compared and regarded in their points of agreement. In certain other cases, a conception is obtained (not from any intuitive source, but) from some already existing generalization, either in the same department, or in another department. The 'idea' for embracing water waves, and sound vibrations, was found by Newton in the 'Pendulum;' and apart from the facts themselves, no better 'idea' has yet been given.

The connexion of Body and Mind has its 'idea' yet to seek. There has hitherto prevailed the bad idea of External and Internal. In short, the most suitable comparison wherein to embrace the relation has not been obtained from any source, intuitive or other. One approximation is a 'union of distinct states.'

The arriving at difficult identifications, that is, the tracing of similarities shrouded in diversity, by such devices as have been advanced in logic with a more special eye to proof, may be viewed in the first place with regard to *generalization* as such; not distinguishing the notion from the principle or proposition. What pertains specially to the induction of the general proposition, namely, the *concomitance* of distinct properties, is best considered apart.

Under the Deductive Method (p. 96) attention was called to three helps to the discovery of generalities—multiplication of instances, close individual scrutiny of instances, and selection of the least complicated instances. A wider view of the available resources must now be taken. We have to see how far the thorough explication of the reasoning processes, and of all the adjuncts to reasoning, called forth by the comprehensive Logic of Proof, can be brought to bear also in the striking out of suggestions to be submitted to proof or disproof.

The first great practical lesson derivable from Logic, and applicable in a much wider sphere than proof, is to impress us with Generality as the central fact of science and of all knowledge transcending individuals. After we have gained possession of a certain range of facts, the next great aim is to generalize them to the uttermost. This is not all. In proportion to the compass of any agreement, ought to be the pains taken with it, and the prominence given to it. We have urged, under the Logic of Medicine, the prime importance of generalizing the Diseased Processes and General Therapeutics, because of the wider compass of their application. In everything else, the rule holds. The biologist should take no rest until he has exhaustively accumulated instances of the great fact of Assimilation, under every possible variation of circumstances. In like manner, the physical concomitants of mental processes need to be searched out in all their innumerable modes, in order to rise to the generalities of the connexion.

The severest etiquette of the most punctilious system of ranks and dignities in society is as nothing compared with the graduation of estimate and of respect to be shown to generalities of different grades. It is a grave logical misdemeanour ever to give an inferior generality precedence over a superior, or to treat the two as of equal consequence, or even for a moment to be unaware of their relative standing. We may give all due consideration to the phenomenon of falling bodies as a wide fact co-extensive with the surface of the earth; but in presence of the superior sway of the law of gravity through-

out the solar system, the terrestrial fact must sink into a second place in our esteem.

The next great application of Method, as an aid to discovery, consists in the use of the various Forms or Formalities, elaborated with a view to proof. This is the largest part of the present subject.

Logicians have always striven to set forth the value of Order, method, and explicitness, in complicated statements. Hamilton's dictum—making explicit in the statement what is implicit in the thought—has been received as a happy enunciation of one function of logic. Mr. Mill remarks,—'One of the great uses of a discipline in Formal Logic, is to make us aware when something that claims to be a single proposition, really consists of several, which, not being necessarily involved one in another, require to be separated, and to be considered each by itself, before we admit the compound assertion.' This is the disentangling or analyzing function of the syllogism, and is deservedly extolled as perhaps its highest utility. It is a direct remedy for the weakness of the mind formerly adverted to (p.398).

We may, however, go farther back than the exposition of Syllogism for valuable aids growing out of the logical formalities. All the Equivalent Propositional Forms are instrumental as means of suggestion. They enlarge the compass of any given proposition, by unfolding all its implications; many of these not being disposed to rise to view of themselves, or without the stimulus of the formal enunciation. Of all the modes of Equivalence, probably the Obverse is the most fruitful and suggestive; this has become apparent on many occasions, in the course of the present work; we may instance especially negative defining. Next in value is Conversion; the converting of A by its legitimate form is a check to the blunder of supposing the subject and predicate co-extensive in universal affirmations; and the arresting of the mind on the road to impending error seldom ends there, but is also a start in the search for truth. Even the immediate inference from the Universal to the Particular is suggestive of facts not previously in the view.

Much could be said as to the unsystematic but wide-ranging mode of Equivalence by Synomyous terms, or by varying the ways of expressing the same proposition. Although somewhat ensnaring, this is a fruitful and suggestive operation. Its power consists in resuscitating from the stores of the past all the various known examples of the proposition; to which

also may be added even illustrations and analogies. We know from many celebrated instances, how mere opulence of phraseology gives the semblance, and occasionally the reality, of superior insight The Shakespearian wisdom, the stirring apothegms of Pope, have their source, not in the scientific process of the intellect, but in the suggestiveness of exuberant phraseology.

The Methods of INDUCTIVE Elimination, both directly and indirectly assist in Discovery. The collection and comparison of instances, to comply with the method of Agreement as a method of proof, will in many cases lead to new and improved generalizations. A man can scarcely go through the labour requisite for establishing a law of high generality upon adequate evidence, without adding to his knowledge of the law. Especially is this likely to happen in working the Method of Agreement, whose exigencies are exactly those of inductive discovery.

The same remark applies to the union of Agreement in Absence with Agreement in Presence; and there is the additional force and incisiveness that always belongs to the working of the negative side.

The method of Residues, to which Sir John Herschel called special attention, was by him expressly commended as an aid to Discovery.

The importance of Concomitant Variations has already been signalized, and will be again referred to.

Without dwelling farther on the specific virtues of the several methods, we would call attention to the value of a *complete scheme* of Inductive Proof, in urging a search for instances to fill up all its requirements. He that has thoroughly mastered the experimental methods, desires to bring up in favour of every important principle a series of particulars under each one of them separately; an operation as fertile for discovery as it is thorough-going for proof or disproof.

The remark is not confined to the methods of experimental elimination. The greater number of propositions or laws may derive evidence through the Deductive Method, and through Chance and Probability also. The wish to satisfy all possible methods of establishing a law is a wholesome stimulus to enquire after the very facts that improve the character and extend the application of the law. The consilience of Induction and Deduction is the very highest art that the human intellect can command, not merely for proving difficult propositions, but for getting hold of propositions to be proved.

All this is to repeat in another shape, and in a grander sphere, the function of the Syllogism in insisting that there should be produced an explicit major and an explicit minor premise in any pretended ratiocination. Every inductive instance should be viewed in its proper character, by reference to the method that it subserves. An instance of Agreement should be given as such; a Deductive proof should be quoted under that description. If the Logical rules are not arbitrary, but founded on a correct analysis of the scientific processes, the conscious reference to them, on all different occasions, must be a relief and a comfort to the perplexed enquirer.

The Deductive operation, understood not formally as in the syllogism, but really and materially, as in finding new applications and extensions of inductions, is a pure generalizing process. It consists in identifying particulars with other particulars, exactly as in the properly inductive operation. It is the same march of mind continued and prolonged. An induction so called is merely a certain collection of particulars, with a generalized expression superadded; deduction is the bringing in of new particulars. The difference of the two is not in the mental operation; it is in the end that is served. The inductive particulars are those necessary for giving the generalized expression, and for proving it as a law of nature; the subsequent deduced particulars, not being required for establishing the generality, receive illumination from the other class. In both cases the effort of discovery is identical; it is the bringing together in the mind by the force of resemblance a host of particular facts from all times, places, and subjects. Before the induction is gained, the particulars contribute to its establishment; after it is gained, the new particulars are receivers and not givers of benefit.

The processes included under DEFINITION—the canons for Defining, General Naming, and Classification—are processes of Discovery directly, and of Proof indirectly. Mr. Mill calls them subsidiary to Induction, meaning Inductive Proof. Every step indicated under those several heads has an immediate efficacy either in suggesting generalities, or in purifying them from ambiguity, perplexity, and confusion. It is impossible to make a single well concerted move in any of the paths marked out in these several departments without gaining an enlargement of views, or the means of some future enlargement.

Everything of the nature of an antidote to inadvertent and confused thinking, everything that reduces information to the

shape best suited for recollection and reference, everything that facilitates the comparison of resembling facts—must be enrolled among the means of Discovery. These various ends are explicitly aimed at by the prescriptions contained under Definition, Naming, and Classification. To substantiate the allegation would be to rehearse the methods explained under those heads. The amassing of particulars, positive and negative, with a view to Definition, is the express act of generalization, and brings with it discoveries of concomitance, as well as generalizes notions. All the devices of Naming are intended primarily to ease and assist the understanding in arriving at new truths. The machinery of Classification is still more strikingly the economizing of the faculties in amassing and in manipulating knowledge.

When the generalizing process has expressly in view the discovery of laws, or *concurring* properties, a most material help (as formerly seen) is afforded by Tabulation, especially according to a scale of degree. Failing this, great stress is always laid upon *extreme* instances. These are the glaring and striking instances of Bacon and Herschel (see the Research on Dew, p. 68). The method of exhibiting gradation by Curves is considered one of the best ways of suggesting numerical laws.

Mr. Darwin has given an account of the steps that led him to propound the doctrine of Development under Natural Selection. It affords an interesting commentary on the foregoing enumeration of the causes that prompt original suggestions.

'When I visited, during the voyage of H.M.S. *Beagle*, the Galapagos Archipelago, situated in the Pacific Ocean about 500 miles from the shore of South America, I found myself surrounded by peculiar species of birds, reptiles, and plants, existing nowhere else in the world. Yet they nearly all bore an American stamp. In the song of the mocking-thrush, in the harsh cry of the carrion-hawk, in the great candlestick-like opuntias, I clearly perceived the neighbourhood of America, though the islands were separated by so many miles of ocean from the mainland, and differed from it in their geological constitution and climate. Still more surprising was the fact that most of the inhabitants of each separate island in this small archipelago were specifically different, though most closely related to each other. The archipelago, with its innumerable craters and bare streams of lava, appeared to be of recent origin; and thus I fancied myself brought near to the

very act of creation. I often asked myself how these many peculiar animals and plants have been produced: the simplest answer seemed to be that the inhabitants of the several islands had descended from each other, undergoing modification in the course of their descent; and that all the inhabitants of the archipelago had descended from those of the nearest land, namely America, whence colonists would naturally have been derived. But it long remained to me an inexplicable problem how the necessary degree of modification could have been effected, and it would have thus remained for ever, had I not studied domestic productions, and thus acquired a just idea of the power of Selection. As soon as I had fully realized this idea, I saw, on reading Malthus on Population, that Natural Selection was the inevitable result of the rapid increase of all organic beings; for I was prepared to appreciate the struggle for existence by having long studied the habits of animals.' (Domestication, vol. I., p. 9).

Throughout the entire logical scheme, the *analytic* separation already insisted on, is an invaluable help to the faculties under the complications of natural phenomena. To enable us to view separately whatever can be separately viewed is the motive for such artificial divisions as Structure and Function in biology, Physical Side and Mental Side in psychology, Order and Progress, Theory and Practice in politics, Conservation and Collocations in cause and effect, Description and Explanation everywhere.

The process of Invention in the Arts and business of life, is amenable to the general rule of keeping the mind fresh upon the most likely sources. The mere *cogitating* process in practical constructions is exactly the same as in the solving of geometrical or other problems. Certain data are given, a certain construction is required; there is an intervening chasm that has to be bridged. The habit of analytical separation is of avail in this instance also. The mind should steadily view one point at a time, drawing out connexions with each by turns. Thus, to take a simple geometrical construction: given the vertical angle, the base, and the altitude of a triangle to construct it. Now the base is given, and we have to follow out the deductions and implications of the two other data—altitude and vertical angle—with a view to arrive at some known process that will construct the triangle. Let us consider separately what the *altitude* will suggest. Now, a certain fixed altitude implies that the apex of the triangle will lie somewhere in a line parallel to the base; consequently, if

we draw such a parallel, we limit the place of the apex to that line. Turn next to the given *angle*. Considering how to erect upon a given base a triangle with a given vertical angle, we are reminded that upon the given base may be constructed an arc of a circle, such as will contain that angle. The next step is to find a means of constructing the proper arc; the operation of discovery is exactly the same; and brings us at length to some construction that we can perform. We then unite our two threads hitherto followed out in separation. The parallel line first suggested, and the arc next found out, give by their intersection an apex to the desired triangle. It is our previous knowledge that must forge the links of connexion between what is given and what is required; but the analytic habit concentrates the attention *by turns* on each datum, and each outgoing from it; and this is probably the utmost that mere art or method can do for us in constructive inventions.

The uncertainty as to where to look, for the next opening in discovery, brings the pain of conflict and the debility of indecision. This is a case fit to be met by the collective wisdom of a generation. There might at intervals be held a congress on the condition-of-science question, to decide, according to all the appearances, what problems should be next taken up.

Lessons may be drawn from the history of Errors, as well as of Truths. All the Fallacies are beacons both in discovery and in proof. Every source of confusion is an incubus on invention. More particularly, the excessive devotion to the concrete, and to the artistic interests nourished by it, may amount to a total disqualification for scientific originality, whose very existence is in the domain of abstraction.

Certain widely prevailing tendencies of natural phenomena have been indicated as of value in prompting discovery. Such are the Law of Continuity, and the maxim that Nature works by the Simplest Means. Both these principles are uncertain in their scope; which, however, does not prevent them from being used to give suggestions; it only disqualifies them from being conclusive evidence. If we are careful to verify our hypotheses, we are at liberty to obtain them from any source. Still, the mind that has become largely conversant with the ways of nature will find many more fruitful sources of suggestion than either of those principles.

I.—HISTORICAL EVIDENCE.

Two leading branches of Evidence, applied in practical life, are Legal Evidence and Historical Evidence. The two departments have much in common. The evidence both in courts of law and in matters of history is probable, and approaches to certainty by the summation of probabilities.

The following abstract of Historical Evidence represents the maxims in use among historians at the present day, as summarized by Sir G. C. Lewis.

The object of History is the recital of facts—of events that have actually occurred.

In the case of contemporary history, the writer may be able to rely upon his own observations, or upon original documents obtained from authentic sources. Personal knowledge was the basis of much of Xenophon's Anabasis, Polybius' History, Cæsar's Gaelic War, and Lord Clarendon's History of the Rebellion. But the greater part even of contemporary history must repose on the evidence of witnesses.

To a historian, not himself cognizant of the events he narrates, the sources of information fall under one or other of two classes:—(1) Monuments, ruins, coins, and generally all ancient remains; and (2) the evidence of Witnesses. From the former exclusively is derived whatever we know of the pre-historic age; in the same way as geology is built on inferences drawn from fossils and the nature and position of rocks. It is only with regard to history resting upon the testimony of witnesses that rules of historical evidence apply.

Two points demand the notice of one seeking to verify any alleged historical fact. (1) Does the evidence of the witness exist in an authentic shape? and (2) Is it true? The first regards the accuracy wherewith the evidence has been transmitted to us; the second, the worth of the evidence itself. The means of knowledge of the witnesses, the goodness of their memory, their judgment, their general veracity, their special interests,—are all to be considered. This the historian has in common with a jury or a judge, except that he has to deal with men long since dead, and whose character there is more or less difficulty in ascertaining. What forms the peculiar subject-matter of rules of historical evidence is not therefore the worth of the evidence, but the accuracy of its transmission.

The supreme canon of historical evidence is that all testi-

mony must be *contemporary*, or received directly or through trustworthy tradition, from contemporaries. 'Whenever any event is related in histories written after the time, and not avowedly founded on contemporary testimony, the proper mode of testing its historical credibility is to enquire whether it can be traced up to a contemporary source. If this cannot be done, we must be able to raise a presumption that those who transmitted it to us in writing received it, directly or through a trustworthy tradition, from contemporary testimony. If neither of these conditions can be fulfilled, the event must be considered as incurably uncertain, and beyond the reach of our actual knowledge.' (Lewis's Methods of Politics, I. 270.)

This rule is universally recognized as *inclusive;* whatever is established by such testimony is credible. There is not, however, the same unanimity, in admitting it as *exclusive;* or that whatever is not authenticated by external evidence is uncertain. A stringent application of the rule makes such havoc of ancient history, that many learned men have been tempted to exercise their ingenuity in trying to pick out of the mass of tradition some certain indications of the true course of events. The same impulse that first led to the invention of fabulous history—an inability to rest content with a background of historical ignorance—now misleads critics and historians. They expect by a species of historical divination to strip off the false additions to the ancient stories—to sift from the fables the grains of genuine fact. Yet it would seem as if the utmost that could be gained would be that the event *may* have happened as supposed. To prove that the event did happen, nothing can make up for the want of external attestation. Internal improbability may enable us to doubt or disbelieve an alleged fact; internal probability cannot assure us that the fact was as alleged; the only decisive evidence is the testimony of credible witnesses.

The difference between the internal and the external standards of evidence appears remarkably in the results of their application. Sir G. C. Lewis, refusing to admit internal consistency or plausibility as a warrant for belief, rejects the accepted History of Rome down to the war with Pyrrhus. Niebuhr, on the other hand, divides this period into three parts that, in his opinion, differ greatly in historical value. The era of Romulus and Numa (80 years) he considers wholly fabulus, from Tullus Hostilius to the first Secession of the Plebs (179 years) is mythico-historical, a twilight of fable

and fact; from the Secession of the Plebs to the war with Pyrrhus (213 years) is solid history. It would perhaps be too much to condemn Niebuhr's efforts on *a priori* grounds. To what extent a license of guessing may be permitted will best be seen when it has been tried by different men. If the result should be a general concordance of opinion, we might reasonably infer that the ancient narratives, although they conceal, nevertheless betray the truth. If, however, this method lead to irreconcileable and endless diversity of opinion, it must cease to be regarded as valuable or trustworthy.

Evidence may be transmitted in two ways, by writing or by oral tradition. These may be considered separately.

The value of a written memorial consists generally in this, that its credibility is not impaired by the mere action of time. An English mathematician named Craig held that all testimony was enfeebled by mere lapse of time, and thus the evidence of Christianity would at length be reduced to zero. Assuming that that event would coincide with the end of the world, he calculated when the end would come. Laplace adopts the same view, and says that even in spite of printing, the events that are now most certain, will, in the course of ages, become doubtful. But this must be regarded as an error. The only deterioration that a document can suffer from mere lapse of time is the increased difficulty of weighing the credibility of the writer. A written memorial has none of the disadvantage of a statement handed down orally from one person to another, and losing value at each transmission.

Yet the evils of transmission are not wholly overcome even with written records. Two doubts may arise, (1) whether the writing is ascribed to its real author, and (2) whether it is free from interpolation and mutilation.

'In many cases the original memorial is preserved; as in ancient inscriptions upon stone, brass, or other durable material. Such are the inscriptions, in the arrow-headed character, on the Babylonian bricks, and on other Assyrian monuments; the hieroglyphics engraved on the remains of Egyptian architecture; and the numerous Greek and Latin inscriptions found in different parts of Asia Minor, Africa, and Europe, and belonging to different ages. Ancient coins, with their legends, are another original record of the same kind, as well as historical sculptures or paintings, such as the bas-reliefs on the column of Trajan, or the Bayeux tapestry. Ancient documents, likewise, containing the authentic records of many important events and public acts, are preserved in the original

in national archives. Such, for instance, is Domesday-book, the rolls of Parliament, court records, charters, and other official registers and documents kept in public depositories.' (Lewis, I. 201).

In authenticating books and documents, whose safe-keeping is not specially provided for, great difficulty is often experienced. A mere tradition regarding the origin of a document would be exposed to nearly all the doubts that attach to oral tradition. 'Hence the importance of archives, chartularies, public libraries, and other safe places of deposit, which are under the care of trustworthy guardians, appointed and controlled by public authority.' The law of England requires that written documents, before they can be tendered as evidence, be produced from the proper place of custody.

The difficulty of ascertaining the genuineness of ancient books, is forcibly illustrated by the controversy regarding the Platonic Dialogues. Until the close of last century, thirty-six dialogues were attributed to Plato on the authority of Thrasyllus, whose list dates from about the commencement of the Christian era. As, however, Plato died more than three hundred years before, the canon of Thrasyllus stands in need of corroboration and support. Most of the German Critics allow it very little weight, and test each dialogue upon own evidence, external or internal, but chiefly internal. This unavoidably gives rise to great diversity of opinion, and there is little agreement as to what ought to be rejected or retained. Ast, the least sparing critic, leaves only fourteen out of thirty-six. Mr. Grote, on the other hand, discards the German criticism, and putting little stress upon the indications of authorship contained in any reputed dialogue of Plato, searches for more decisive evidence, so far as it can be got, in the history of the books mentioned by Thrasyllus.

Plato died B.C. 347, and left his works to the care of the school continued under Xenophanes and Speusippus. We do not possess any list of their master's works resting on their authority, and the first solid ground we reach (apart from the few incidentally mentioned or alluded to by Aristotle) is an extract from the works of the Grammaticus Aristophanes, who lived at Alexandria from B.C. 260 to B.C. 184. He comes thus a century after Plato, and nearly two centuries before Thrasyllus. He divided the dialogues into trilogies, and several of these are mentioned by Diogenes Laertius. They are remarkable as containing the names of some of the compositions that are least acceptable to the critics, and that would be hard

to vindicate on internal evidence. These are Leges, Epinomis, Minos, Epistolae, Sophistes, Politicus. It would be interesting to know what means Aristophanes had of distinguishing the genuine from the spurious works, if any such then existed.

For two centuries after the death of Plato, the Academy was kept up as a philosophical school, with an unbroken succession of presidents. The chief treasure of the school was the works of the master. It cannot be too much to assume that there was provided a safe custody for the MSS. of Plato, and a ready means of verifying any alleged works. Plato is better off in this respect than any of his great contemporaries, Socrates, Demosthenes, Euripides, or Aristophanes.

Aristophanes, the Grammaticus, was head of the Alexandrian Library. He was taught by Callimachus, who preceded him in the office of Chief Librarian. Callimachus is the author of the 'Museum,' a general description of the Alexandrian Library; and less important authors than Plato, as e.g. Democritus, are mentioned by him. It is then highly probable that such a library as that of Alexandria would contain copies of one of the foremost Greek philosophers. And, considering the ease of verification, it is most likely that the Librarian would assure himself that his copies were authentic.

There were, in the time of Thrasyllus, spurious dialogues. Whence came these, and by what criterion did he discard them? If Aristophanes and Thrasyllus (who appears also to have been connected with Alexandria) depended upon the library there, they must be allowed to speak with great weight; but if they proceeded wholly or partially upon internal evidence, they have less claims on our attention than the better-equipped modern critics. Mr. Grote supposes that the spurious works were made for the demand in Greece and Asia Minor, and for the library started by the Kings of Pergamus as a rival to the Alexandrian.

So much for the difficulty of settling the real authorship. The other point to be determined is the freedom of existing copies from spurious additions or omissions, accidental or intentional.

In the first place, errors will accidentally creep in, by the mere act of copying. It is impossible to guarantee strict accuracy in transcription. This is recognised in jurisprudence, and the English law refuses to admit any copy where the original can be produced. But the reason of the law does not apply with the same force in history. A very slight alteration in a deed might sometimes alter the meaning of it; and, more-

over, there is often an exceedingly powerful temptation to tamper with deeds. Now, the value of a copy of MS. depends on its accuracy, and the motives for falsifying history are far weaker. It is therefore considered that the works of classical authors are preserved to us substantially as they were when published. Such variations as there are do not affect the general accuracy of the copies that have reached us.

In the second place, changes may be made intentionally, to suit a purpose. We are told that Solon inserted a verse in the Iliad with a view to confirm the title of the Athenians to the possession of Salamis. At an early period, authentic lists or *canons* of authors and their works were prepared to guard against deception. Short writings are most easily forged, and hence there are numberless forgeries of letters; but we find examples of falsification at greater length in the poems of Ossian. Ecclesiastical writings contain many forgeries, made for the purpose of propagating or confirming opinion. The motive for executing forgeries is often to make money by arousing curiosity; but in such cases as Ossian, it is merely the pleasure of deceiving the world. Literary forgeries are generally detected by internal evidence—by inconsistencies, anachronisms, imitations of subsequent writers, and other marks of recent composition.

When we have sufficient assurance that a work is both authentic and genuine, written by its reputed author, and not tampered with in the course of transmission, we have still to consider the worth of the testimony. Besides examining our author's means of information—whether he writes as an eye-witness or at second hand, or at what other remove from eye-witnesses—we must enquire into his character for veracity and his motives to depart from the truth.

There is often intentional perversion or suppression of the truth, especially in Autobiography, as Cæsar's Gallic Wars, and Napoleon's Memoirs of his Campaigns. Vanity, a love of the marvellous, and party spirit, operate in the same direction. There are Catholic and Protestant histories of the Reformation; Whig and Tory histories of England. The accounts of modern campaigns and military operations differ very much according to the side the writer belongs to. Many inaccuracies arise from not taking the trouble to investigate the truth. History may be blended with fiction for a didactic or moral purpose, as in Xenophon's Cyropædia.

The ancient historians departed from strict truth, by introducing into their works speeches composed by themselves.

One fourth of the history of Thucydides is composed of such speeches. Lucian thought it a sufficient excuse for introducing fictitious speeches, that they were suitable to the character of the speaker, and appropriate to the subject. Polybius is the only writer of antiquity who condemns the practice, for, he says, the object of the historian is not to astonish the reader, but to record what was actually done or said. This opinion has been followed by modern historians, and the manufacture of speeches has therefore ceased. The same thing, however, in substance, is still done, although introduced as part of the history, namely, interpreting acts and suggesting motives. It is a great, though perhaps not uncommon, error, to treat as history what thus owes its origin to conjecture.

Another perversion of history is *mythical* history. 'The original author of such a legend must, no doubt, be at first conscious that it is the spontaneous product of his own invention, unattested by any external evidence. But the fiction is suggested by prevailing ideas and feelings; it interweaves existing facts and customs into its texture; it furnishes an apparent support to institutions or practices for which the popular mind seeks an explanation; it fills a void which is sensibly felt, and supplies food for an appetite whose demands are at once urgent and general. The inventor of such a legend, therefore, differs altogether from the author of a novel or romance, who lays before the public a tale avowedly fictitious, and which they accept as such.' Examples may be found in Greek mythology, in the fabulous heroes of mediæval chivalry, and in the lives of mediæval saints. Such legends have a use, not as describing events, but as throwing a reflected light on the circumstances and character of those who invented, believed, and circulated them. The most difficult case to the historian is not pure mythology, but the blending of myth and history, which lures men on to search for fact, but leaves them unable to distinguish it from fiction. The history of Greece, from the first Olympiad to the Persian war, and of Rome, from Tullus Hostilius to the Punic wars, illustrates this intermediate period of twilight and uncertainty.

The second mode of transmitting evidence—Oral Tradition, loses credit very rapidly with the lapse of time An account of an event, diminishing in evidentiary value at each remove from the original eye-witness, very soon ceases to have any value at all. This has always been more or less recognized. Polybius confined himself to what he learned from eye-witnesses of the preceding generation, and thus begins his

consecutive history about twenty years before his birth. Newton thought that oral tradition might be trusted for 80 or 100 years; and Volney remarks that the Red Indians had no accurate tradition of facts a century old.

The average value of oral tradition may be enhanced in various ways. During the panic caused by the mutilation of the Mercuries, and the fear of treasonable attempts to establish a despotism, the Athenians recurred to the government of Pisistratus and his sons, which had begun nearly 150 years and ended 100 years before that time. Thucydides describes the Athenians as referring, entirely by oral tradition, to the attempt by Cylon—a fact at the time 180 years old. That event had however created a hereditary curse in the powerful family of the Alcmaeonidae, and the memory of it was revived at different times by public acts. The Dies Alliensis, the anniversary of the fatal battle of the Allia, was doubtless kept up by uninterrupted usage from B.C. 390. Festivals, emblems, antiquated offices, serve to fix tradition, and keep alive the recollection of events. The *Interrex*, in Rome, who continued to be appointed during the Republic in the vacancy of the consulship, was a reminiscence of a period of elective kings. The King of the Sacrifices, like the King Archon at Athens, is also a decided indication of the regal period. There were, moreover, many buildings, monuments, and public places in Rome associated with the names of kings. The existence of laws, like the Twelve Tables, inscribed on metal or stone, may serve to perpetuate a correct oral tradition.

Rubino, the author of a work on the early Roman Constitution, has laid down some rules on this subject. He divides oral tradition into two classes, one referring to the constitution, and the religious and civil institutions connected with it, the other embracing the more common material of history, wars, negotiations, and the striking events that give interest to the history of Rome. This last alone was committed to the exclusive keeping of oral tradition, and was much more liable to error and uncertainty than the traditions relating to the constitution. To some extent, constitutional usage implies a knowledge of precedents. Such information in all probability existed at the beginning of the Second Punic war; but it might not reach far back without the help of documents. There is no reason to suppose that accurate knowledge would have gone back beyond a century. It is not possible to draw any broad line between constitutional history, and the common events of history; we could not discuss the changes in the

English Constitution during the seventeenth century, without a knowledge of the events that gave birth to them.

There is one case where oral transmission makes an approach to the value of transmission by writing. This happens when the memory is assisted and checked by a set form of words, especially if the form be metrical. Cæsar tells us that the secrets of the Druidical religion were contained in a great number of verses, in committing which to memory a druid would spend twenty years of his life. In like manner, the Iliad and Odyssey were perpetuated by a race of professional reciters and rhapsodists.

K.—EXPLANATION OF SOME LOGICAL TERMS.

The following terms, not being deemed essential to any of the important doctrines of Logic, may not have been made fully understood in the previous exposition. As they occasionally occur in logical discussions, short explanations of them are here appended.

ARGUMENT is used in several different senses. Apart from its more popular significations, a disputation, a chain of reasoning, and even a chain of events (the argument of a play), its meaning is not fixed and uniform among logicians. Some apply it to an entire syllogism, premises and conclusion, some to the premises only as the grounds of the conclusion, while Hamilton maintains that its proper meaning is the middle notion in a reasoning,—'what is assumed to argue something.' So Mansel holds that the word should be applied only to the Middle Term.

CATEGOREMATIC.—A distinction is drawn between words that can stand alone as subject or predicate of a proposition, as man, stone (Categorematic); and words that can stand only in company with other words, as all, none (*Syn*categorematic).

DICTUM DE OMNI ET NULLO.—This applies directly to the First Figure alone. It is usual to give similar principles for the other Figures, and among these we may notice the *dicta* given by Mr. Mansel in his notes on Aldrich (p. 86).

'Principle of second figure. *Dictum de Diverso.* If a certain attribute can be predicated (affirmatively or negatively) of every member of a class, any subject of which it cannot be so predicated, does not belong to the class.

'Principles of third figure. I. *Dictum de exemplo.* If a certain attribute can be affirmed of any portion of the members

of a class, it is not incompatible with the distinctive attributes of that class. II. *Dictum de excepto.* If a certain attribute can be denied of any portion of the members of a class, it is not inseparable from the distinctive attributes of that class.'

ENTHYMEME.—A syllogism with one of its premises suppressed in the enunciation. Hamilton argues against the prominence given to Enthymeme as a division of syllogisms, on the ground that they are not a special form of reasoning, but only an elliptical mode of expression. He also shows (what is done more elaborately by Mr. Mansel) that Aristotle understood by Enthymeme not an elliptical syllogism, but 'a syllogism from signs and likelihoods,' or a syllogism with the major premise only probable.

IGNAVA RATIO or *Sophisma pigrum* is the master fallacy of Fatalism. It might be classed with fallacies of Non-observation. The Fatalist argues that, if a thing must happen, it will happen whether he interfere or no; overlooking that his own agency is one of the co-operating causes.

INTUITIVE—SYMBOLICAL.—We often employ words and symbols without fully realizing their meaning. This Leibnitz called Symbolical as distinguished from Intuitive, Knowledge, ideas and sensations fully realized in consciousness. We can conceive a yard, a mile, or even ten or twenty miles, in the full reality of the extent; but of the distance between the earth and the moon, the sun, or one of the fixed stars, we have no proper conception; we may, however, express such distances in figures, which are intelligible as such. This would be a symbolical conception.

MODALS.—(See Part I., p. 99). The opposition of Propositions has been applied to Modals, in the following statements.

If the matter be *necessary*, all *affirmatives* must be *true*, and all negatives false,

If the matter be *impossible*, all negatives must be true, and all affirmatives must be *false*.

If the matter be *contingent*, all *particulars* must be *true*, and all *universals false*.

Here the meaning of 'necessary' is no more than universally true, as all men are mortal, all matter gravitates. 'Impossible' is universally false; all men are gods. 'Contingent' means partly true and partly false; Some men are wise.

PORPHYRY'S TREE.—This is a tabular arrangement showing different grades of generality. The example chosen ranges from the summum genus *Substance*, to the infima species *Man*,

ending with two individuals. It may be exhibited thus, in a form better described by the Greek name, Porphyry's *Ladder* (κλίμαξ) :—

Substance
Corporeal Incorporeal
(Body)
Animate Inanimate
(Living Body)
Sensitive Insensitive
(Animal)
Rational Irrational
(Man)
Socrates Plato

PREDESIGNATE is a term applied by Hamilton to propositions, having their quantity expressed by one of the signs of quantity, All, None, &c. The contrasting term is *Preindesignate*. The terms commonly used in logic are *Definite*, *Indefinite*.

SIMPLE APPREHENSION is defined by Whately as 'the operation of the mind by which we mentally perceive or form a notion of any object.' It is the same as Perception, whereby we know things in the actual or concrete—a house, a tree. By another faculty, designated Abstraction, we conceive things in the general.

SUFFICIENT REASON.—Under this title Leibnitz stated the law of Causality. Everything that exists must have a 'sufficient reason' for its existence. The attempt has been made to prove certain truths, such as the law of perseverance of uniform motion in a straight line, on the ground that no sufficient reason can be given why a body should either lose its velocity or deviate to one side or the other. The same line of remark has been used with the principle of virtual velocities.

SOPHISMA POLYZETESEOS and SOPHISMA HETEROZETESEOS are two ingenious Greek Sophisms. The first was alluded to under Definition. Choosing a word having a doubtful margin of application, the sophist asks whether it applies to such and such a case, and goes on putting the question to one contiguous case after another, until he has drawn the respondent palpably beyond the range of the word, when he demands the difference between the last case admitted and the first refused. Such words as *heap*, *calf*, &c., are suitable: the sophist asks—Was it a calf to-day, will it be a calf to-morrow, next day, and so on; the respondent cannot say on what day it ceases to be a calf, and becomes a heifer. The *Heterozeteseos* (Sophism of

Irrelevant Question) decoys a person into committing himself by a categorical answer—'Have you cast your horns?—If you answer, I have; it is rejoined, Then you have had horns: if you answer, I have not, it is rejoined, Then you have them still.'

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